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EARTHQUAKE HAZARDS REDUCTION

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

ON

REAUTHORIZATION OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM (NEHRP)

MARCH 29, 1990

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EARTHQUAKE HAZARDS REDUCTION

THURSDAY, MARCH 29, 1990

U.S. Senate,
Committee on Commerce, Science and Transportation,
Subcommittee on Science, Technology and Space,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:38 a.m., in room SR-253, Russell Senate Office Building, Hon. Albert J. Gore [chairman of the subcommittee] presiding.

Staff members assigned to this hearing: Mike Nelson, professional staff member; and Fiona Branton, minority staff counsel.

OPENING STATEMENT BY SENATOR GORE

Senator Gore. The subcommittee will come to order.

I want to welcome all of our witnesses and guests and tell you all how much we look forward to the hearing today. This is a reauthorization hearing for the National Earthquake Hazards Reduction Program. We call it NEHRP for short.

Congress established NEHRP in 1977 to improve our understanding of earthquakes and to reduce the threat they pose. The Earthquake Hazards Reduction Act of 1977 pulled together different agencies to create a more coherent and more coordinated national earthquake program. Just as importantly, the act provided additional funding for earthquake research and earthquake preparedness.

When the program started, we hoped that within a few years scientists would find a way to predict the date, time, location and magnitude of earthquakes, giving us the warning time needed to prevent the thousands of deaths and injuries that can be caused by a major earthquake. There were hopes that engineers would discover how to cheaply and effectively make buildings invulnerable to earthquakes.

Well, unfortunately the hopes of the '70s disappeared with severe budget cuts in the '80s and with the handling by the last Administration of the earthquake program. Since 1980, funding for the National Earthquake Hazards Reduction Program has dropped more than 35 percent in real dollars. The program has been left limping along with less than one third of the funding needed to adequately address the earthquake threat.

Many promising avenues of research were simply not pursued, and while scientists and engineers were able to make important strides, too often the results of their research never left the lab because there was not the staff or funding needed to transfer it to the architects, contractors, urban planners and policymakers who could make good use of it.

If you read the original Earthquake Hazards Reduction Act, you will see that many of the goals of that program remain unmet today. There is still much, much more which needs to be done to reduce our vulnerability to earthquakes. We are just not directing enough of our resources to adequately protect Americans from earthquakes.

As all have recently been reminded, earthquakes represent one of the most powerful forces nature can unleash. A single catastrophic earthquake in the Memphis area, or in Seattle, or in Los Angeles, could kill thousands of people and cause billions of dollars in damage, and such an earthquake will occur, most likely in our lifetimes.

In the continental United States there have been five such devastating earthquakes in the last 200 years. We are due for another one, and scientists tell us there is a greater than 50 percent chance of a catastrophic earthquake in California in the next 30 years. When that quake happens—and it will happen—the death toll could, if we are not prepared, exceed 10,000 people, and the damage could, if we are not prepared, top $50 billion. That is $200 for every man, woman and child in the entire country.

Yet, what are we doing to get prepared and to reduce that enormous threat? At the Federal level, we are spending less than $75 million a year on the National Earthquake Hazards Reduction Program. That is about 30 cents for each man, woman and child. Never have we asked a program to do so much with so little.

It is clear we need to increase our investment in this program for the savings later on, and in order to reduce the death toll and damage later on, when the earthquakes occur. The Loma Prieta earthquake showed us what investing in earthquake preparation can do.

Sherlock Holmes solved a mystery one time by noticing the dog that did not bark. Well, the buildings that did not fall in the San Francisco Bay Area stood as mute witnesses to the value of earthquake hazards mitigation.

This Subcommittee had a hearing in Memphis last December at which a earthquake expert from the San Francisco Bay Area was joined by one from the Soviet Union who was their leading expert on the Armenian earthquake, and even though the Armenian earthquake was smaller in size and magnitude than the one at Loma Prieta, they lost 20,000 people, while in the San Francisco Bay Area less than 100 people were killed. The difference, very simply, was preparation.

Buildings, highways and other facilities that are built to withstand a major earthquake cost a little more, but when you know the risk is real, it is certainly worth it. The news media focused, after the Loma Prieta earthquake, on the collapsed buildings and fires in the marina district and the crushed automobiles beneath the Cypress Street viaduct, but again the real story was all the buildings and all the bridges and highways that remained intact.

The moral is that you can save lives and buildings and millions of dollars by investing in efforts to reduce the threat of earthquakes. They recovered their entire investment in earthquake preparation many, many, many times over, just in the aftermath of that one event.

Unfortunately, though, it is a moral not everyone has heard. Outside of California, there is still a tendency to say, earthquakes? They are not my problem. Of course, as we know, in 37 States and for over 150 million people across America they are a problem, even if largely unrecognized.

Memphis, the largest city in my home State, lies just a few miles from the New Madrid fault zone, which was responsible for three of the largest earthquakes ever recorded, and fortunately the people of Memphis know about that threat.

But we need to do a good deal more everywhere in the country, especially in the high risk areas, to get prepared for it, and that is what we are going to focus on here today. One of the goals of the program is to provide that focus on a continuing basis.

In addition to helping the private sector prepare for earthquakes, the NEHRP was created to reduce the vulnerability of Federal buildings, facilities and lifelines. Soon after NEHRP was created, the Interagency Committee on Seismic Safety and Construction was established to bring together 25 different Federal agencies involved in building, leasing and regulating buildings and lifelines. The Committee is chaired by Dr. Richard Wright. He is one of our witnesses here today.

The mission of the ICSSC is to make sure the Federal Government sets a good example when it comes to earthquake safety. Unfortunately, they have not had the high-level support needed to do their job. For almost ten years Dr. Wright and the ICSSC have pushed for government-wide seismic standards for Federal buildings, but throughout the years of the Reagan Administration, OMB vetoed those standards.

Finally, last January, three months after the Loma Prieta earthquake severely damaged several Federal buildings while private buildings withstood the shock, President Bush signed an executive order requiring development and implementation of government-wide seismic standards for all new, Federal buildings.

We welcome that first step, but we still need to address the larger problem posed by existing Federal buildings. There has not even been a comprehensive survey of the earthquake safety of Federal buildings in the high-risk areas. If we do not know the extent of the problem, it is going to be very hard to address it. There is also a great deal of work to be done on federally-owned and regulated highways, pipelines and other essential lifelines.

A major earthquake on the New Madrid fault zone would cut oil and gas supplies to the entire East Coast, would knock out critical bridges across the Mississippi River, sever railroad lines and worst of all even close down Federal Express, which would be a most serious blow to the economy of the United States.

To discuss the vulnerability of highways and Federal buildings and what their agencies are doing to eliminate this problem, we have witnesses here today from the Navy, which has really exercised leadership, and the Department of Transportation and others.

I look forward to hearing from all of our witnesses, and before I do that I want to recognize my friend and colleague Senator Gorton.

OPENING STATEMENT BY SENATOR GORTON

Senator Gorton. Mr. Chairman, as I have listened to you, I have reflected on the fact that for two senators of opposite parties living 2,000 miles from one another, we seem to share a remarkable breadth of common interests.

In this case, your interest is partly due to your natural intellectual inquisitiveness, and partly due to the threat which earthquakes pose for the State of Tennessee. In my case, of course, I have similar interests because Washington State has the second greatest degree of risk, from the point of view of people, from earthquakes.

As a consequence, I think I want first to thank you for allowing me to participate in this hearing, although I am not a member of your Subcommittee, and to repeat to a certain extent some of the points that you have made. Last fall's earthquake in and around San Francisco clearly focused the Nation's attention on something most people would prefer to ignore—the death and destruction that can hit a city, a countryside, a community, without warning, in just a matter of a few seconds.

If any good can arise out of tragedy, we can take consolation in the fact that many of us—and I include this senator among that group—vowed to apply the lessons learned from San Francisco to better prepare ourselves for another earthquake.

In February, Senator Adams, Governor Gardner of Washington State, and I sponsored a forum in Seattle on earthquake preparedness. 1,300 people jammed into the conference room for the all-day seminar, when we started out expecting maybe 200.

We heard from the Geological Survey, from the Federal Emergency Management Agency, from State and local officials, from a dozen members of the community involved in lifeline industries such as communications, utilities and transportation. While we heard about many positive activities which were taking place in Washington State to prepare for an earthquake, it was obvious to everyone that the task before us was an enormous one.

According to FEMA, Washington State, as I have already said, is the second largest at-risk population, after California. The Geological Survey and the Federal Emergency Management Agency have been doing a planned five-year research project in the Pacific Northwest. They are about half-way through that study, and the findings are profound and frightening.

While we were aware of the fact that our area was prone to shallow earthquakes, we have recently had a 7.1 in 1949-and a 6.5 in 1965, which I personally experienced. We did not know that we were also at risk for a great quake, equivalent to the magnitude that has been previously predicted for California.

Let me read a letter that the Director of USGS wrote to Congressman Fazio in response to his inquiry about future funding requirements, and I quote:

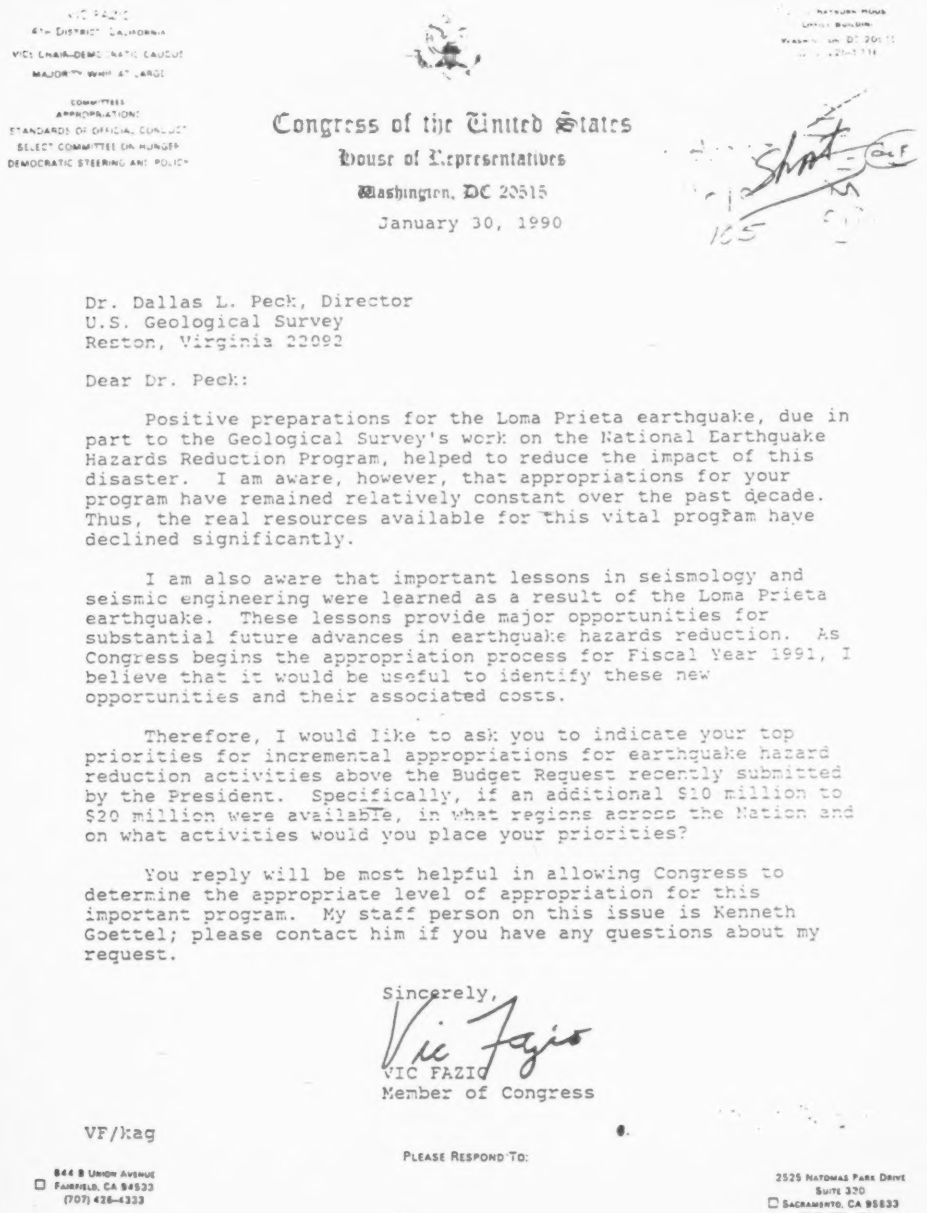
> Scientists have long understood that the area from the Puget Lowland to the Willamette Valley is subject to magnitude 7 earthquakes. The North American plate and the subducting slab have been the source of eight such earthquakes since the 1870s, and these have formed the basis of earthquake hazard analysis for that reason.

Over the past decade, and after some scientific debate, it has become apparent that the region may also be subject to subduction zone earthquakes. Elsewhere along the eastern Pacific Ocean margin such events have had magnitudes as large as 9.5. Several new lines of evidence discovered over the past few years suggest that very large earthquakes have struck the region, possibly as recently as 300 years ago.

The current program in the Pacific Northwest is funded at $3 million a year. Given the new evidence that has been uncovered, I believe that it is imperative that USGS stays in our region and increases its work there.

Congressman Fazio asked the Geological Survey in what regions and on what activities priorities should be placed if additional funds were available. I would like to include that response for the record.

[The letters follow:]



VIC FAZIO
4th District, California
Vice Chair—Democratic Caucus
Majority Whip at Large

Committees:
Appropriations
Standards of Official Conduct
Select Committee on Hunger
Democratic Steering and Policy

Congress of the United States
House of Representatives
Washington, DC 20515

Rayburn House
Office Building
Washington, DC 20515

January 30, 1990

Dr. Dallas L. Peck, Director
U.S. Geological Survey
Reston, Virginia 22092

Dear Dr. Peck:

Positive preparations for the Loma Prieta earthquake, due in part to the Geological Survey's work on the National Earthquake Hazards Reduction Program, helped to reduce the impact of this disaster. I am aware, however, that appropriations for your program have remained relatively constant over the past decade. Thus, the real resources available for this vital program have declined significantly.

I am also aware that important lessons in seismology and seismic engineering were learned as a result of the Loma Prieta earthquake. These lessons provide major opportunities for substantial future advances in earthquake hazards reduction. As Congress begins the appropriation process for Fiscal Year 1991, I believe that it would be useful to identify these new opportunities and their associated costs.

Therefore, I would like to ask you to indicate your top priorities for incremental appropriations for earthquake hazard reduction activities above the Budget Request recently submitted by the President. Specifically, if an additional $10 million to $20 million were available, in what regions across the Nation and on what activities would you place your priorities?

You reply will be most helpful in allowing Congress to determine the appropriate level of appropriation for this important program. My staff person on this issue is Kenneth Goettel; please contact him if you have any questions about my request.

Sincerely,

Vic Fazio
VIC FAZIO
Member of Congress

VF/kag

PLEASE RESPOND TO:

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Fairfield, CA 94533
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☐ 2525 Natomas Park Drive
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(916) 978-4381

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

In Reply Refer To:
WGS-900233
Mail Stop 905

MAR 21 1990

Honorable Vic Fazio
House of Representatives
Washington, D.C. 20515

Dear Mr. Fazio:

Thank you for your letter of January 30, 1990, and the interest you expressed in the role of the U.S. Geological Survey (USGS) in the Earthquake Hazards Reduction Program. We agree that important lessons are being learned from the October 17, 1989, Loma Prieta earthquake. We want to assure you that our staff and external grantees (who will receive about half of the funding appropriated to the USGS) are working very hard to take maximum advantage of the $12 million USGS portion of the Dire Emergency Supplemental Appropriation to study the causes and effects of the earthquake and to accelerate application of the lessons from the Loma Prieta event elsewhere in the Nation. As I am sure you are aware, the budget request recently submitted by the President for fiscal year 1991 is constructed to address the highest needs and priorities within the available resources while also addressing the need to reduce the Federal deficit. In support of the administration's deficit reduction objectives, we would recommend that any increase above the budget levels for the Earthquake Hazards Reduction Program be offset by corresponding reductions elsewhere. You asked specifically, however, in what regions and on what activities priority should be placed if additional funds in the range of $10 to $20 million were available. High priority should be assigned to each of the following areas:

Northern California: The Loma Prieta earthquake occurred some 60 miles from the highest concentrations of population and investment in the San Francisco Bay area. Seismologists unanimously agree that comparable or stronger earthquakes will someday strike even closer to areas of high population density. We are in the process of reviewing the estimates of the probability for such future earthquakes along the recognized fault segments of highest concern, the San Andreas fault along the San Francisco Peninsula, the Hayward fault along the East Bay, and the newly reevaluated Rodgers Creek fault in the Petaluma-Santa Rosa region. Proposed activities would be aimed at improving estimates of the probability and effects of future earthquakes and at developing the basis for realistic seismic zonation. A Loma Prieta-size earthquake on the Hayward fault without adequate long-term and short-term preparations could be extremely serious.

We are just beginning to evaluate another class of fault that has produced destructive earthquakes even though they are not expressed at the surface. For example, faults that generated the two magnitude 6.5 earthquakes which severely damaged the Sacramento Valley towns of Vacaville, Dixon, and Winters in 1892, remain unrecognized. Similar "hidden" faults were likely responsible for many of the most serious historic earthquakes elsewhere in the Nation, including the 1872 Washington State earthquake, the 1886 Charleston, South Carolina, earthquake, and the 1935 Helena, Montana, earthquake, as well as the 1987 Whittier Narrows earthquake in southern California. We believe that additional funds could be effectively spent to evaluate both the recognized and "hidden" faults in the greater San Francisco Bay region, to assess and describe the hazards from ground shaking, liquefaction, and landslides associated with future earthquakes along them, and, by taking advantage of recent advances in technology, to improve geophysical monitoring along them. Also, knowledge gained in Northern California will have wide applicability throughout earthquake-prone portions of the Nation.

Southern California: Southern California combines a very high seismic hazard with a very high concentration of population and investment to create the region of highest seismic risk in the Nation. Even though for historical and logistical reasons, the USGS earthquake program began with a focus in northern California, we have endeavored over the last decade to address pressing issues across the Nation while at the same time increasing our efforts in southern California. The earthquake problem in southern California is particularly complex because the active faults span a broad area and show a diverse character. In addition to the long recognized San Andreas fault and its major branches through the region, for example, much of the greater metropolitan area in southern California is underlain by recently recognized~~,~~ though buried, thrust faults which are more difficult to study because they do not break the ground surface. The 1987 Whittier Narrows earthquake serves as an example of the hazard posed by this class of faults. Thus, in view of the clear need for increasing earthquake studies in the southern California area, the USGS has been working with universities in the region and the California Division of Mines and Geology to establish a cooperative Southern California Earthquake Center. We intend to use a portion of the funds from the Dire Emergency Supplemental Appropriation to help initiate this Center, and we have joined with the universities in seeking funds for its establishment from the National Science Foundation's Science and Technology Centers Program. The objective of this Center would be to improve earthquake monitoring capabilities, to analyze and interpret earthquake phenomena, to study earthquake effects (including ground shaking and ground failure), and to provide a focus for technically accurate earthquake information as a foundation for regional earthquake hazard reduction measures. The 1991 budget includes no funding for the Center.

New Madrid: New Madrid, Missouri, the largest settlement in the region in the winter of 1811-1812, and its surroundings were devastated by four earthquakes estimated at magnitude 8. The New Madrid region is the most seismically active east of the Rocky Mountains in the United States; earthquakes of magnitude 6.4 struck in 1843 and of magnitude 6.8 in 1895. Estimates indicate that earthquakes with magnitudes ranging from 6.0 to 6.5 can be expected at least once per century, and the region is particularly vulnerable to losses from such future earthquakes. Houses, office buildings, industrial plants, storage facilities, and lifeline infrastructure in Memphis, St. Louis, and several moderate-sized cities generally were not designed to survive seismic shaking. In addition, the thick, poorly consolidated alluvial materials of the area will amplify the ground motion. Damaging ground motion would affect an area about 20 times larger than a comparable earthquake in California. The USGS has long considered the New Madrid seismic zone a high priority area and, at the request of the Congress, had scheduled a workshop prior to the Loma Prieta event to prepare a study plan. The plan resulting from that workshop is nearly completed. Most of the funding the USGS received as part of the supplemental appropriation will be allocated for work in California, but as requested by the Senate, a significant part will be spent on activities in the New Madrid area. Because we have annually allocated less than $1 million for New Madrid studies for the past few years, the augmentation permits a significantly increased level of activity for fiscal year 1990. However, the type of research needed to adequately address the critical problems of the region will require several years to complete. Additional funding would improve regional monitoring activities, enhance our ability to identify the source of the earthquakes, initiate paleoseismic investigations, and allow evaluation of ground response and delineation of hazards.

Pacific Northwest: The Pacific Northwest is subject to earthquakes that occur in three distinct source regions. Scientists have long understood that the area from the Puget Lowland to the Willamette Valley is subject to magnitude 7 earthquakes. The North American plate and the subducting slab have been the source of eight such earthquakes since the 1870's, and these have formed the basis of earthquake hazard analysis for the region. Over the past decade, and after some scientific debate, it has become apparent that the region may also be subject to subduction zone earthquakes. Elsewhere along the eastern Pacific Ocean margin such events have had magnitudes as large as 9.5. One of the enigmas of the Pacific Northwest is that no earthquakes of this type have been recorded there since European settlement. Several new lines of evidence discovered over the past few years suggest that very large earthquakes have struck the region, possibly as recently as 300 years ago. Because of the historical earthquakes that have occurred in Oregon and Washington and the relatively dense urban population from Eugene, Oregon, to Bellingham, Washington, the USGS initiated a modest research program to identify and describe the source and potential for earthquakes, as well as the associated risks (loss of life and property from ground shaking and ground failure). That program is funded at about $3 million annually; external investigators receive about half of that amount. Because of the limitations on the level of funding and personnel, as well as logistical problems presented by the lush vegetation and thick unconsolidated deposits, this program has not proceeded as rapidly as we had anticipated. The funding levels would adequately support the start of a comprehensive program to address the possibility of a subduction zone earthquake through the deployment of monitoring systems, analysis and interpretation of data, paleoseismic investigations, and determination of likely levels of shaking and extent of ground failure.

National Seismograph Network and Support for Regional Seismic Networks: The USGS, in cooperation with the Nuclear Regulatory Commission (NRC), is establishing a digital National Seismograph Network for the United States. Partial funding for stations east of the Rocky Mountains has been supplied by the NRC; the USGS will support the balance of the network, in part from the supplemental appropriation, as well as accept responsibility for developing, deploying, and maintaining the network. This National Seismograph Network will provide a uniform backbone for earthquake monitoring across the Nation. In addition, this initiative will provide partial support for independent regional networks. The National Seismograph Network will consist of about 100 stations throughout the United States, Puerto Rico, and the Virgin Islands, and each station will record three-component information with high dynamic range and broadband frequency response as well as strong ground motion. Such information is of critical importance for structural design purposes. It will also provide standardized, high quality data that will allow us to more fully understand and describe earthquakes occurring in varied tectonic environments. An augmentation would allow us to complete and maintain the system and to provide partial support for regional networks and the study of earthquake hazards in other regions of the country, such as the Intermountain Region, Alaska, Hawaii, and New England.

For illustrative purposes, allocation of augmentative funding would be:

Northern California	$4.9M	$3.7M	$2.5M
Southern California	5.4	4.0	2.7
New Madrid	4.2	3.9	2.8
Pacific Northwest	3.5	1.9	1.0
National Seismograph Network	2.0	1.5	1.0
	$20.0M	$15.0M	$10.0M

As with other USGS earthquake activities, the work would be carried out in close cooperation with State, local, private sector, and university colleagues; a substantial portion of funds would be awarded to nonfederal institutions and agencies for research and implementation activities.

Thank you again for your interest. If we can be of further assistance, please let us know.

Sincerely yours,

Dallas L. Peck
Director

Senator GORTON. The research done by USGS provides critical data our States and local communities need to make decisions about earthquake preparedness. I believe that the Federal Government must support this research at adequate levels.

I therefore hope that this Committee will support an increase in funding for USGS of $15 million, an increase in the President's budget request from $35 to $50 million. Additional funds could be used to accomplish the needed work outlined in this letter in the Pacific Northwest, California, and in the New Madrid region.

I was pleased to see that the President's budget request does increase FEMA's funding from $6 million to $13 million, but I should also like to hear from FEMA officials as to whether this increase is sufficient to meet its needs.

Mr. Chairman, earthquakes are inevitable, but their results are not. In October of last year the bay area was rocked by a quake of 7.1 on the Richter scale. 62 people died, 41 alone in the Nimitz freeway collapse. Less than a year before that, in December of 1988, a lesser quake of only 6.8 on the Richter scale hit in Armenia. 25,000 Armenians perished, as virtually every major structure near the epicenter collapsed.

Clearly, through understanding first where earthquakes are likely to hit and then through improved design, construction, and building codes we can do a great deal to withstand even strong earthquakes. I urge the Committee to support and increase funding for the National Earthquake Hazards Reduction program.

Senator GORE. Senator Stevens?

OPENING STATEMENT BY SENATOR STEVENS

Senator STEVENS. Mr. Chairman, I am sorry to drop in, but we have Defense hearings going on that are quite important this year, but there is nothing more important to us than the subject before us, in view of our State.

I see people at the witness table who know a great deal more about this issue, and I just want to thank you for holding the hearing. I will read the testimony with interest. It seems like every time I go home we have another earthquake. I do not know whether there is some connection between that.

But also I was surprised to find out that there may be a connection between some of our volcanoes and the volcanic activity in the plates that are so active in the Pacific. I hope that this hearing will bring out some of those connections, because I find that we are developing a great deal of interest in our new Institute of Volcanic Science that you all have supported so well, and I thank you for that.

This is going to be, I think, a decade of renewed interest in the Pacific system, if I understand what I just heard when I was in Alaska last week. We are going to expect continued activity from Mount Redoubt and perhaps a little calliope up and down the Aleutian Chain, from what the indications are, maybe additional volcanic activity in the Pacific region.

But Mr. Chairman, you just have to have gone through what we went through in the period of the aftermath of the great Good Friday earthquake in Alaska—that was in 1964—to really have an awareness of the total devastation of a major earthquake, and we were saddened to see what happened in California. I really think we should have a great deal more effort in this area, and sufficient resources to keep us posted on what is going on, so we can have as much warning as possible.

Incidentally, just for your information, Mr. Chairman, we did have warning on Mount Redoubt, and we have been able to set up systems to live with that on-going phenomena. I hope that we can find ways to similarly study the earth to have substantial advance knowledge of what is going on in the earthquake area, too.

I am really at a loss for words to tell you—my heart tells me that we ought to be giving you more assistance than anywhere else, because of the great devastation that the Good Lord can bring to us if these forces are active in our hemisphere, and we ought to, as Senator Gorton says, be interested in what happens in the world also.

So thank you for holding the hearing.

Senator GORE. Well, thank you, and I enjoyed your statement. Of course, the largest earthquake in the history of the United States was that Good Friday quake in 1964 in Alaska, and the second largest was in Memphis in 1811, and then the others in the first part of 1812, which incidentally knocked down the scaffolding here in Washington while the Capitol dome was under construction.

Yet in spite of our historical experiences, we remain like the fellow who did not fix his roof while the sun was shining because it was not causing him any problem, and yet when it rained he did not feel like getting out in the rain to fix it. That is the way we are with earthquakes.

When we have a big earthquake, we immediately provide lots and lots of money for the aftermath, and the disaster relief effort, but we do not really provide much to improve the research and the monitoring so we can be prepared the way the San Francisco Bay Area was prepared. Then after the quake has faded in memory a little bit, then of course the sun is shining and people are not interested in even talking about it.

Well, the sun may not be shining outside today, but we have got an opportunity here to change this pattern. That is why we are anxious to learn more from our witnesses today and do right by the Nation's effort to predict earthquakes and improve our preparedness.

Our first panel is made up of Mr. Grant Peterson, who has served as the Associate Director for State and Local Programs and support at FEMA for several years and was responsible for coordinating the Federal response to Hurricane Hugo and the Lomo Prieta earthquake—quite a year for you, Mr. Peterson—as well as dozens of smaller disasters.

Also Dallas Peck, who for the last eight-and-a-half years has served as director of the USGS, which receives by far the majority of the funding for the earthquake program. In addition he chairs the Committee on Earth Sciences, an interagency committee which coordinates the research done by Federal agencies on natural disasters.

Dr. James F. Hays is a geochemist and Director of the Earth Sciences Division of the Geosciences Directorate at the National Science Foundation which funds basic research in geology and geophysics.

Dr. Robert Hanson is also at NSF, an earthquake engineer and presently Director of NSF's Biological and Critical Systems Division of the Engineering Directorate, and finally Dr. Richard M. Wright, a structural engineer and Director of the Center for Building Technology at NIST in the Department of Commerce.

Mr. Peterson, we will begin with you. Before we do, I want to ask if our ranking member would like to make a statement.

Senator DANFORTH. No, thank you, Mr. Chairman. I am very interested in being here and look forward to the hearing.

I do have a statement that Senator Pressler would like to have included in the record.

[The statement follows:]

OPENING STATEMENT BY SENATOR PRESSLER

Thank you, Mr. Chairman. I am pleased to be here today, and look forward to the testimony we will receive from our distinguished witnesses.

Last October, the entire country was shocked by a relatively large earthquake—but not the expected "big one"—in California. The earthquake measures 7.1 on the Richter scale, making it stronger than the disastrous Armenian earthquake in December of 1988. However, the damage and the number of lives lost in the Bay Area were significantly less than in Armenia, even though the California earthquake was a stronger magnitude. The California earthquake, while tragic, was a clear demonstration of the benefits of being prepared.

At least 39 of our 50 states, and a major proportion of our population, are vulnerable to moderate or major seismic risk. Even my home state of South Dakota is not immune. Just last January, an earthquake measuring 3.9 on the Richter scale hit near Rapid City, South Dakota. It was felt in the towns of Hot Springs, Hermosa, and Pine Ridge, and was followed by a 3.0 aftershock on March 2.

Most of the people in the United States who are at risk of an earthquake are not as well prepared as the people of California. Fortunately, since the National Earthquake Hazards Reduction Program was started in 1977, we have come a long way toward preparing for an earthquake. Federally-funded research, including the continental scientific drilling program, has provided us with information to predict with greater accuracy where earthquakes will occur. This has created greater public awareness and better preparation. However, as the San Francisco earthquake demonstrated, we still have a long way to go to eliminate the hazards that exist throughout the nation. I am pleased that we are having this hearing to address the effectiveness of the Federal earthquake program, and what more needs to be done to make sure that the United States is prepared for an earthquake regardless where it might strike.

Senator GORE. Mr. Peterson, on a personal note I wish to thank you for your response to the recent flooding catastrophe in Southeast Tennessee. We had an opportunity to be on the telephone quite a bit during that period of time, and I am grateful for your response, and for providing the assistance which was received there. We are here on another subject today, but I did want to thank you.

Now, without objection your prepared statement will be included in full in the record, and please proceed as you wish.

STATEMENT OF GRANT C. PETERSON, ASSOCIATE DIRECTOR FOR STATE AND LOCAL PROGRAMS AND SUPPORT, FEDERAL EMERGENCY MANAGEMENT AGENCY

Mr. PETERSON. Thank you, Mr. Chairman and distinguished members.

I am very pleased to appear today to support the reauthorization of the Earthquake Hazards Reduction Act. FEMA is designated lead agency, and we have before you the four principle NEHRP agencies.

We have forwarded to you for consideration a request for a two-year authorization of the National Earthquake Hazard Reduction Program or NEHRP for short. This request includes authorization of funding for fiscal years 1991 and 1992 and for the four principal NEHRP agencies.

The earthquake hazard, as you know and which has been articulated here today, is a national threat. The purpose of the NEHRP is to reduce the risk to life and property in the United States from earthquakes through the establishment and maintenance of a multi-disciplinary earthquake program.

We believe significant progress has been made under the NEHRP to reduce the earthquake threat, but there is still much, much more left to be done. In my statement for the record I address what FEMA intends to pursue in detail. I will cover just a few of those items this morning, Mr. Chairman. But first, on behalf of the NEHRP agencies, I want to thank you personally, Mr. Chairman, for the work you did on the $20 million supplemental appropriation that was recently provided by Congress to the NEHRP.

FEMA has allocated $2.2 million of its share of the supplemental appropriation to state and local governments. This amount doubles the amount of money we now have available for state and local governments, and we are most appreciative.

FEMA has been aggressively working with the states since 1980 to develop a state earthquake capability. FEMA is also working to ensure the existence of a coordinated national urban search and rescue capability and $800,0000 of the supplemental appropriation has been allocated to that effort.

This allocation was made based upon recognition of a potential need identified from lessons learned from the recent earthquake in California and the one that occurred in Armenia.

The supplemental appropriation will serve as a foundation for the enhanced funding the President is requesting in his 1991 budget submission for FEMA's earthquake program. This request doubles FEMA's earthquakes budget from approximately $6 million in fiscal year 1989 to over $13 million proposed for fiscal year 1991. The significant increase will allow FEMA to pursue innovative strategies, to build capability on the state and local level. In fact, it will allow us to increase state participation in the earthquake program overall.

We currently fund 17 states, and this number is expected to grow substantially with the additional funding that is now available. FEMA's funding to the states is done on a matching basis, which has been supported by Congress. We believe having the states share the cost of their federally supported projects is an effective way of developing and sustaining their commitment to the earthquake program overall. The enhancement of the funds to state and local governments due to the supplemental appropriation and the President's proposed budget increases will also require a match.

Recently FEMA discussed funding enhancements with representatives from those states currently participating in the program and those interested in joining at a special meeting in Memphis, Tennessee. FEMA is presently considering input received from the states on cost-sharing and the formula for distributing the supplemental appropriation and the proposed fiscal year 1991 budget increase.

Another FEMA goal based upon the recommendation of the expert review committee is to develop a uniform approach in performing loss studies for all risk areas across the United States in 1991. We will be developing a state-of-the-art manual for nationwide use in performing loss studies, and we will embark on a long-term program of conducting new loss studies as well as revising existing studies that need to be updated.

I now would like to cover some of FEMA's new NEHRP leadership initiatives. As you will recall, I announced last year at the hearing in Memphis FEMA's intention to pursue these initiatives, and we have kept that commitment.

First, FEMA is working to establish an advisory committee of persons outside the Federal Government with expertise in the earthquake arena. In the past the NEHRP has benefitted from utilizing outside expertise like the expert review committee.

Second, FEMA in cooperation with the other NEHRP agencies will convene a policy workshop next month for invited earthquake experts. The purpose is to address the major issues confronting the NEHRP and recommend innovative approaches which the NEHRP agencies can consider. And, third, FEMA has reactivated the senior level policy coordinating group. In fact, next week the group will meet once again to discuss an interagency cooperative project on formulating an overall NEHRP project for fiscal year 1992.

I would now like to turn to the important subject of technology transfer. As you know, the NEHRP develops a technical research base through the program of USGS, NSF and NIST. This data is then transferred into effective earthquake hazard reduction tools for use at the state and local levels and in the private sector.

Every aspect of FEMA's earthquake program involves technology transfer. FEMA's proposed budget increase places additional emphasis on practical mitigation measures for state and local governments and the private sector. This is important because the built environment, poses the greatest threat to life.

FEMA will continue to disseminate mitigation techniques developed for new buildings and will continue to expand our work in seismic design standards and work toward the development of standards for existing buildings and lifelines in coordination with the NIST.

I also want to note that President Bush recently signed Executive Order 12699 which directs Federal departments and agencies to implement seismic design and construction for new Federal buildings. This Executive Order may prove to be one of the most significant contributions toward reducing the earthquake threat. It should serve as a positive example to the state and local building design and construction community and, hopefully, be an impetus for the adoption of the NEHRP provisions by model building code groups which would be a great step toward a national standard.

Finally, Mr. Chairman, FEMA will also continue to coordinate the development and implementation of the Federal Response Plan to a Catastrophic Earthquake. As you know, the plan involves 26 Federal departments and agencies and serves as a blueprint for providing Federal support to state and local response efforts.

Portions of the Federal plan were implemented during the Loma Prieta earthquake, and the plan has been exercised with the State of California several times. FEMA will focus on building response capabilities during FY 1991 and FY 1992 in the central United States.

Other Federal agencies are working toward building a national level of preparedness, and those activities are covered in my written statement which I would like to submit for the record. I believe the initiatives I mentioned this morning as well as those contained in my written statement demonstrates FEMA's commitment to the NEHRP.

That concludes my oral remarks. I would be happy to answer any questions, and thank you for the privilege of being here today, Mr. Chairman.

[The statement follows:]

STATEMENT OF
GRANT C. PETERSON
ASSOCIATE DIRECTOR
STATE AND LOCAL PROGRAMS AND SUPPORT
FEDERAL EMERGENCY MANAGEMENT AGENCY

Mr. Chairman and distinguished members of the Subcommittee, I am pleased to appear today to support the reauthorization of the Earthquake Hazards Reduction Act of 1977, as amended. The Federal Emergency Management Agency (FEMA), as designated lead agency, has forwarded for your consideration a request for a two year authorization of the National Earthquake Hazards Reduction Program (NEHRP). This request includes authorization of funding for Fiscal Years 1991 and 1992 for the four principal agencies of the NEHRP: FEMA, United States Geological Survey (USGS), National Science Foundation (NSF), and National Institute for Standards and Technology (NIST).

The earthquake hazard, as you know, is a national threat. All 50 states are vulnerable to earthquakes, 39 of them at moderate to high risk, including 17 currently identified as being at high risk with high populations. The purpose of the NEHRP is to reduce the risks to life and property in the United States from earthquakes.

The NEHRP recognizes the importance of implementation of mitigation programs carried out principally by FEMA as well as the other NEHRP agencies. Furthermore, the NEHRP recognizes the important contribution scientific research makes toward reducing the earthquake threat. While the Administration is proposing to increase FEMA's earthquake budget for Fiscal Year 1991, continued support also is being proposed for the earthquake-related research efforts of the USGS, NSF, and NIST since scientific research is the foundation of the overall NEHRP.

FEMA'S PORTION OF THE NEHRP SUPPLEMENTAL APPROPRIATION

The supplemental appropriation of $20 million for the NEHRP agencies passed by the Congress following the tragic occurrence of the Loma Prieta Earthquake will allow FEMA to expand its efforts in earthquake mitigation, preparedness, and response planning. As a result, FEMA will be able to expand the number of states receiving earthquake funds with its $3 million share of the supplemental appropriation. As you know, FEMA funds represent the only continuous federal funding resource available to states and their local governments to build and implement earthquake mitigation, preparedness, and response programs. We have allocated $2.2 million of the supplemental appropriation to state and local governments. The allocation almost doubles the amount of money we now have available to go to state and local governments.

FEMA also is working to ensure the existence of a coordinated national urban search and rescue capability and $800,000 of the supplemental appropriation has been allocated to that effort. This allocation was made based upon recent lessons learned from the Loma Prieta Earthquake in California and the one that occurred in Armenia. I recently chaired the first national workshop on urban search and rescue sponsored by FEMA, which had participation from over 90 specialists from across the country. The workshop was just one part of a two-year effort to identify existing capability and shortfalls so that a national resource of urban search and rescue teams is inventoried, trained, and certified and ready to respond in the next earthquake.

FEMA'S PROPOSED EARTHQUAKE BUDGET FOR FY 1991

The supplemental appropriation will serve as a foundation for the enhanced funding the President is requesting in his budget submission to Congress for Fiscal Year 1991 for FEMA's earthquake program. The President is requesting for Fiscal Year 1991 a doubling of FEMA's earthquake budget -- from approximately $6 million in Fiscal Year 1989 to over $13 million proposed for Fiscal Year 1991. The significant increase will allow us to pursue innovative strategies to build the level of state and local capability and put into effect earthquake hazard mitigation, preparedness, and education programs. This increase will also provide FEMA with the resources to acquire the expertise and advice that meaningfully support lead-agency activities under the NEHRP.

FEMA's proposed budget increase places additional emphasis on technology transfer and implementation of practical mitigation measures by state and local governments and the private sector. Such activity is important because the built environment presents the greatest threat to loss of life. The performance of buildings in the Loma Prieta Earthquake which were designed to modern seismic codes demonstrates the effectiveness of such mitigation tools in protecting lives and property.

I now would like to discuss some of FEMA's proposed new initiatives under the NEHRP.

ENHANCEMENT OF STATE AND LOCAL GOVERNMENT EARTHQUAKE PROGRAMS

FEMA currently provides funding on a matching basis to 17 states for earthquake mitigation, preparedness, and education programs. The proposed budget increase will allow us to increase the number of participating states and provide additional support for state activities. This number is expected to grow as the earthquake threat is recognized by states at risk and the anticipated increase will make the program truly national in scope.

FEMA also intends to increase program activity on the local level in cooperation with the states based upon the recommendation of FEMA's Expert Review Committee and we are considering several options, including challenge grants. Furthermore, the recent performance of the Bay Area Regional Earthquake Preparedness Project (BAREPP) in the Loma Prieta event reinforced our interest in pursuing local government involvement. FEMA's investment in that project along with the State of California's really paid off in the recent earthquake because local governments and their citizens were prepared and knew what to do.

As you are aware, FEMA's funding to the states is provided on a matching basis which has been supported by the Congress. FEMA believes that having the states share the cost of their federally supported projects is an effective way of developing and sustaining their commitment to earthquake hazards reduction.

Beginning in Fiscal Year 1988, FEMA instituted a three-year phased cost share program which started with a voluntary match by a state in the first year. The phased cost share approach was designed to minimize disruption of ongoing state earthquake hazards reduction projects and give existing as well as future recipients advanced notice of cost share requirements. In the second year of the phased cost share program, Fiscal Year 1989, FEMA required a minimum of a 25 percent non-Federal contribution to the cost of earthquake hazards reduction projects. The minimum share contribution by a state was either in cash or an in-kind contribution. The current FY 1990 cost sharing requirement provides for a minimum non-Federal cash contribution of 50 percent to the total cost of a State's earthquake hazards reduction project. Recipients were notified about the 50 percent cash contribution effective September 1987.

The enhancement of funds to state and local governments, due to the supplemental appropriation and the President's proposed budget increase, will also require a match. Recently FEMA discussed funding enhancement with representatives from the states currently participating in the program and those interested in joining at a special meeting in Memphis. FEMA presently is considering input received from the states on cost sharing and the formula for distributing the supplemental appropriation and the proposed FY 1991 budget increase.

EARTHQUAKE LOSS STUDIES

Earthquake loss studies are the prerequisite to the initiation of many state and local hazard reduction measures. In recognition of the importance of such studies, FEMA worked with the National Academy of Sciences to examine acceptable methodologies available for performing such studies. A significant portion of FEMA's proposed budget increase for Fiscal Year 1991 will support this critical activity. FEMA's goal, based upon the recommendation of the Expert Review Committee, is to develop a uniform approach for performing loss studies for all risk areas across the nation. We intend to pursue that goal by developing a state of the art manual for performing earthquake loss studies that can be used nationwide. In addition, we will be initiating a long-term program of conducting new loss studies for risk areas as well as revising existing loss studies that need to be updated.

NEHRP LEADERSHIP INITIATIVES

To implement a truly national earthquake hazards reduction program, leadership must be exerted to bring together the diverse elements of the NEHRP and different viewpoints among the experts in the earthquake community. The President's proposed budget increase will permit FEMA to establish various mechanisms and strategies which can channel and take advantage of these different interests to benefit the overall implementation of the NEHRP.

FEMA's new NEHRP leadership initiatives are intended to improve overall program coordination and cooperation among the NEHRP agencies as well as provide an objective evaluation mechanism to determine the proper balance of the program. I will now discuss these initiatives.

NEHRP EARTHQUAKE ADVISORY COMMITTEE

To assist FEMA in carrying out its NEHRP leadership role, FEMA is establishing an advisory committee that can provide ongoing input and review by persons outside the Federal Government with expertise in earthquake-related sciences and practical application of earthquake hazards reduction measures. FEMA has had success in the past utilizing outside experts in providing advice on the NEHRP. In fact, the recommendations received from FEMA's Expert Review Committee were very beneficial to us in planning initiatives for the current fiscal year, the supplemental appropriation, and the proposals for next fiscal year.

We envision the advisory committee providing advice, recommendations, counsel, and direction on all major policies and activities of the NEHRP. Consequently, the committee will provide an objective perspective on the completeness and appropriate balance of the NEHRP as it is currently structured. If we are to have a truly national program, then we must have broad participation of all elements of government, the design professions, the academic research community, voluntary agencies, industry and commerce, and the general public. The selection of the committee members is intended to reach out and serve as a conduit to the diverse elements of the earthquake community.

NEHRP POLICY WORKSHOP

Recognizing that there are diverse disciplines on earthquake hazards reduction within the expert community, FEMA in cooperation with the other NEHRP agencies will convene a national policy workshop next month. The purpose of the workshop is to identify the major issues confronting the NEHRP and recommend innovative approaches which the NEHRP agencies can consider. The workshop results then will be integrated into the NEHRP and become a critical component of the upcoming revision to the NEHRP 5-Year Plan. A major goal of the workshop will be to provide an objective review and evaluation of whether the current program emphases are still appropriate for achieving the long term goals of the NEHRP.

NEHRP MARKETING PLAN

While the entire nation is at risk to the earthquake threat, many different interests and audiences do not know that they have a stake in earthquake preparedness, mitigation, and education. These groups, organizations, and interests need to learn about the NEHRP and how they can participate and contribute to reducing the earthquake threat on the local, state, and national levels. Through a well-researched and developed marketing plan, FEMA will identify these missing players, contact and educate them about ways to become involved in the NEHRP, and obtain their involvement and commitment. The earthquake threat is too serious to allow only fragmented application of the NEHRP. We must expand the level of interest and involvement if our aim is to reduce the nation's risk to earthquakes.

REACTIVATION OF NEHRP SENIOR POLICY GROUP

A national program requires aggressive leadership and dedicated commitment by senior management as well as on the staff level. I am proud to say that program managers with each NEHRP agency have worked hard to implement the different program elements of the NEHRP. The most recent accomplishment was the coordination effort among the four NEHRP agencies regarding the funding from the supplemental appropriation. However, I must acknowledge that the Earthquake Policy Coordinating Group (PCG), chaired by FEMA and consisting of senior policy officials from each principal NEHRP agency, has not been very active in recent years. I am personally committed to reactivating that group. In fact, I recently convened the Group and we have agreement among the senior policy managers to pursue the special initiatives I mentioned earlier.

In addition, next week the PCG will be convening to discuss an interagency cooperative project on formulating an overall NEHRP budget request for FY 1992. All NEHRP agencies have agreed in principle to work together in developing a comprehensive budget strategy for the NEHRP as opposed to separate budgetary efforts for each NEHRP agency. It is envisioned that all NEHRP agencies will review the program's overall budgetary needs and make their separate requests based upon a NEHRP consensus.

I want to assure the Congress that there is coordination and cooperation among the NEHRP agencies. First, the PCG has been reactivated as I mentioned. Second, there is on-going activity by the Interagency Coordination Committee (ICC), which consists of the operating program managers from each NEHRP agency. This group, for example, has met seven times since the first of the year.

TECHNOLOGY TRANSFER

Every aspect of FEMA's earthquake program involves utilizing the technical research developed under the NEHRP through the programs of the USGS, NSF, and NIST. Applying this research through a concentrated program of technology transfer is what FEMA's earthquake activities are meant to accomplish. State and local governments, the private sector and, in some cases, individuals are the parties responsible for implementing earthquake hazards reduction measures. Our activities in earthquake education, response and preparedness planning, and seismic design and construction, are oriented toward providing strategies, techniques, and tools for these groups to effect earthquake mitigation. Our funding of state and local governments allows these entities to take these strategies, techniques, and tools and implement programs to reduce the earthquake hazard.

Special recognition must go to the effort that translates research and technology currently available into practical applications in the form of technical handbooks and manuals that are used by both government and the private sector. These tools along with an aggressive program of dissemination and training allow for research to be put into practice among the design and construction professions. We will continue to disseminate much needed mitigation information such as the NEHRP Recommended Seismic Design Provisions for New Buildings, which has been well-received by the building design and construction industries. In fact, adoption of the NEHRP provisions for new buildings as part of the model codes for the Building Code Officials and Code Administrators International (BOCA) and the Southern Building Congress is currently under consideration.

FEMA also is working to address the threat posed by existing hazardous buildings through the development and dissemination of "how to" materials. These materials, which can be used by state and local officials and design professionals, provide methods on how to quickly screen buildings that pose a threat in case of an earthquake and how to strengthen the building.

Lifelines of critical importance to the nation are being examined to determine overall seismic vulnerability and the expected impacts of large earthquakes. A study, begun in 1988, is being conducted for FEMA by the Applied Technology Council to develop a national overview of lifeline seismic risk, including the potential consequences of earthquake damage and disruptions to major lifeline systems.

A major lifelines project initiated at the request of the Congress will soon be underway. This study will consist of a vulnerability analysis of lifelines to an earthquake in the Cajon Pass region of California. The study is expected be analogous to all lifeline systems and yield recommendations on potential mitigation techniques involving new design and construction methods. Furthermore, the study has multi-hazard implications since the impact of an earthquake on certain lifelines could create other types of hazards, e.g., hazardous materials, flood, etc. Consequently, recommended earthquake mitigation techniques from the study could be prototypes for other hazards.

SEISMIC STANDARDS FOR FEDERAL BUILDINGS AND LIFELINES

A recent accomplishment in the area of seismic design implementation on the Federal level was the signing by President Bush of Executive Order 12699 directing Federal departments and agencies to implement seismic design and construction for new buildings. The Executive Order was accomplished through the intense efforts of the four NEHRP agencies, particularly FEMA and the NIST, and was supported by over 25 other Federal agencies directly involved in Federal buildings through membership on the Interagency Committee on Seismic Safety in Construction (ICSSC). The Executive Order may prove to be one of the most significant events leading toward a reduction in the risk from earthquakes. Not only will it serve as a positive example to the state and local building design and construction community, but it will also provide a real reduction in the threat posed by new buildings located anywhere in the nation that are Federally owned, leased, assisted or regulated.

While an Executive Order is in place for new buildings, the adoption of Federal seismic design and construction standards for existing Federal and federally-assisted buildings cannot be implemented at this time. Presently strengthening techniques for existing buildings are being developed. The available techniques, however, must be reviewed and evaluated, including their cost implications, prior to adoption. Identifying available technology and data that can lead to consensus on nationally applicable building techniques for existing buildings is a very complex process.

The adoption of seismic design standards for Federal lifelines also is a very complex issue. In 1987, FEMA in conjunction with technical experts developed an "action plan" for addressing the lifeline issue. Because of the Loma Prieta Earthquake and other events, FEMA, with assistance of these experts will be revisiting the entire lifelines issue. We are prepared to propose that we submit a report to the Congress in 1992 on how best the NEHRP can facilitate seismic improvement to the Nation's lifelines.

We believe NIST can play a significant role in the NEHRP in the areas of technical support to retrofitting existing buildings and lifelines by performing special problem-focused research, testing of design and construction materials, and providing technical review of advances in engineering.

CONTINUED DEVELOPMENT OF FEDERAL RESPONSE CAPABILITIES

FEMA will continue to coordinate the development and implementation of the Plan for Federal Response to a Catastrophic Earthquake. As you know, that plan involves 26 Federal departments and agencies and serves as a blueprint for providing immediate and massive Federal resources that support State and local response efforts.

Portions of the Federal Plan were implemented during the Loma Prieta Earthquake. For example, I convened the Plan's Catastrophic Disaster Response Group in Washington within two hours of the earthquake to ensure that the Federal Government's response was immediate and effective.

The Federal Plan has been exercised with the State of California three times in the last five years. Most recently, we exercised the Plan, last August, two months prior to the earthquake. For the future, FEMA will focus on building response capabilities in other high risk areas. Planning is underway for the central United States with a major workshop to be conducted in 1991 and a tabletop exercise to be held in 1992.

INVOLVEMENT OF OTHER FEDERAL AGENCIES IN EARTHQUAKE PREPAREDNESS

In addition to the four principal NEHRP agencies, several other Federal agencies contribute to the nation's earthquake preparedness. These agencies are the Bureau of Reclamation, Department of Defense, Department of Energy, Department of Transportation, National Oceanic and Atmospheric Administration, Nuclear Regulatory Commission, and Tennessee Valley Authority. A detailed description of each contributing agency's earthquake hazards reduction activities is contained in the National Earthquake Hazards Reduction Program: Fiscal Year 1989 Activities Report to the United States Congress, which was submitted to the Congress and members of the Subcommittee in

January.

In summary, these other agencies contribute to seismic design standards development and implementation, seismic monitoring, and preparedness planning. A historical perspective of the contributing agencies' activities is available and contained in FEMA's publication, To Save Lives and Protect Property: A Policy Assessment of Federal Earthquake Activities, 1964-1987.

CAPABILITY OF OTHER FEDERAL AGENCIES TO RESPOND TO A CATASTROPHIC EARTHQUAKE

Under the Plan for Federal Response to a Catastrophic Earthquake, 26 Federal agencies are involved in providing immediate and massive Federal resources that support State and local response efforts in the event of a catastrophic earthquake. Federal resources and assistance are provided under 10 separate Emergency Support Functions (ESF). Attached is a list of these functions along with a brief description. Also attached is a matrix identifying each participating agency and its role under the plan according to ESF.

Participating agencies are members of the Subcommittee on Federal Earthquake Response Planning and the Catastrophic Disaster Response Group (CDRG). The Subcommittee is the coordinating body for response planning and exercise activity. The CDRG oversees the national-level response support effort. It serves as a mechanism to bring to bear all Federal authorities, resources, capabilities, and expertise that can contribute to an enhanced Federal response capability.

FEMA is currently evaluating its responses to Hurricane Hugo and the Loma Prieta Earthquake and identifying areas of strength and weakness as well as lessons learned. This evaluation will include any observations about the disaster-relief activities of other Federal agencies during these recent extraordinary disasters that could indicate a need for improvement. Although the evaluation study is not yet final, FEMA has identified a number of issues relative to other Federal agencies, primarily in terms of duplication of Federal Disaster Assistance.

It should also be noted that both the Department of Defense (DOD) and Department of Transportation (DOT) participate actively in the Subcommittee on Federal Earthquake Planning and the Catastrophic Disaster Response Group. DOD and DOT were actively involved in response activities during Hurricane Hugo and Loma Prieta Earthquake emergency operations. DOD, particularly, was instrumental in arranging for the first wave of airlifts into St. Croix containing essential emergency communications equipment and other critical personnel, equipment, and supplies.

The U.S. Forces Command's annual Joint Command Readiness Program in 1990 will focus on military assistance in domestic emergencies. We believe this will be an excellent opportunity to educate and assist senior military officers to deal with complex command problems related to domestic emergencies. FEMA and the other primary agencies involved in Federal earthquake response planning also will participate in the conference.

RENEWED COMMITMENT TOWARD THE EARTHQUAKE PROGRAM

Finally, I want to stress that FEMA is committed, as I mentioned last December at the Subcommittee's field hearing in Memphis, to carrying out its lead agency role and enhancing the National Earthquake Hazards Reduction Program. FEMA's commitment to the Subcommittee is pledged by the commitment of additional resources and demonstrated past performance. We will continue to work with earthquake experts as we have in the past and seek their advice on program direction. We will continue to work with our fellow NEHRP agencies to ensure that research data on earthquakes is appropriately transferred in a manner beneficial to state and local and private users. We will continue to enhance our technical assistance as well as our funding to state and local governments to reduce the earthquake threat through mitigation, preparedness, and education. And, we will continue to build, train, and exercise Federal and state response capabilities in preparation for when a catastrophic earthquake occurs.

Mr. Chairman, that concludes my statement. Thank you for the opportunity to appear before the subcommittee.

Senator GORE. Thank you, Mr. Peterson. We are going to hold our questions until everybody has given their statement.

Dr. Peck.

STATEMENT OF DR. DALLAS PECK, DIRECTOR, U.S. GEOLOGICAL SURVEY

Dr. PECK. Thank you, Senator.

Mr. Chairman, Senators, I thank you for the opportunity to offer a few comments on the reauthorization of the National Earthquake Hazards Reduction Program and the role of the U.S. Geological Survey in that program.

I want to especially thank you, Senator Gore, for your efforts and the funds made available to these agencies after the Loma Prieta earthquake. I think that was a good investment that will pay off handsomely, and I also want to thank Senator Stevens for his efforts in providing resources for the joint USGS-Alaska volcano observatory that has placed us in a much better position with the Redoubt eruption than would have been possible without that.

The recent tragic earthquakes in the San Francisco Bay area of California and Soviet Armenia have convincingly shown the need of our Nation to know where earthquake source zones are located, how often we can expect earthquakes of certain magnitudes to occur, how the resulting shaking will affect nearby population centers, and eventually how to improve our ability to predict large earthquakes.

I want to emphasize that there are substantial earthquake risks not only in northern and southern California, but also in the central United States as well as in the Pacific Northwest, the western Inter-mountain region, Alaska, Hawaii, and various areas in the eastern United States as shown on the map attached to my written statement.

The forces within the earth that cause earthquakes have been operating for millions of years and will continue to be active in the distant future. These forces expose many parts of our Nation to the potential for catastrophic losses due to earthquakes, and we have come to acknowledge that the threat is not going to go away.

Careful consideration needs to be given to the future course we set for the National Earthquake Hazards Reduction Program in terms of the overall program direction as well as the authorizations for the responsible agencies to carry out their assigned task within the program.

For over a decade the USGS, in cooperation with the Federal Emergency Management Agency, the National Institute of Standards and Technology and the National Science Foundation, has endeavored to provide our Nation with an accurate understanding of the causes and effects of earthquakes.

The four principal agencies of the National Earthquake Hazards Reduction Program are working together to meet their commitment to reduce the earthquake threat in the United States, and the USGS supports continuation of the present cooperative arrangement of NEHRP.

I would like to emphasize that the USGS is continually making major strides in improving our understanding of the earthquake risks throughout the Nation. We do know many of the characteristics of earthquakes that have affected particular geographic regions in the past.

In addition, our studies of current seismicity provide us with insights into the way that large earthquakes can be expected to occur and how the geologic conditions and manmade structures are most likely to behave as a result of these events.

We are carefully examining, for example, how the variations in local geology cause ground shaking to be amplified and what level of ground acceleration is necessary to induce the ground to liquefy which together caused most of the casualties and economic loss in the recent Loma Prieta earthquake.

In conclusion, the Survey values the guidance and suggestions of the subcommittee as to how we can better serve the needs of the Nation. Although we can point to major gains that have occurred as a direct result of the earthquake program, there is still much to be accomplished, and we look forward to a significant continued role in this very important program.

This concludes my oral statement, and I will be pleased to answer any questions.

[The statement follows:]

STATEMENT OF DR. DALLAS L. PECK

DIRECTOR, U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR
BEFORE THE
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE
OF THE
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE
MARCH 29, 1990

Mr. Chairman and members of the Subcommittee, I thank you for the opportunity to offer a few comments on the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) and the role that the U.S. Geological Survey (USGS) is serving in the NEHRP Program.

The recent tragic earthquakes in the San Francisco Bay area of California and in Soviet Armenia have convincingly shown the need for our Nation to know where earthquake source zones are located, how often we can expect earthquakes of certain magnitudes to occur on those zones, how the resultant shaking will affect nearby population centers, and eventually, how to improve our ability to predict large earthquakes. I want to emphasize, as indicated on the attached map (Attachment 1), that there are substantial earthquake risks not only in northern and southern California, but in the Central United States as well as in the Pacific Northwest, the Western Intermountain region, Alaska, Hawaii, and in various areas of the Eastern United States.

The forces within the Earth that cause earthquakes have been operating for millions of years and will continue to be active into the distant future. These forces expose many parts of our Nation to the potential for catastrophic losses due to earthquakes, and we have come to acknowledge that this threat is not going to go away. Careful consideration needs to be given to the future course we set for the NEHRP, in terms of the overall program direction, as well as authorizations for the responsible agencies to carry out their assigned tasks within the program.

For over a decade, the USGS, in cooperation with the Federal Emergency Management Agency, National Institute of Standards and Technology, and the National Science Foundation, has endeavored to provide our Nation with an accurate understanding of the causes and effects of earthquakes. The four principal agencies of the NEHRP are working together to meet their commitment to reduce the earthquake threat in the United States, and the USGS supports continuation of the present arrangement of NEHRP.

For its part of the program, the USGS has divided its efforts among five broad tasks or program elements. These include the identification and characterization of earthquake source zones throughout the United States, earthquake prediction research, earthquake risk assessment in specific urban regions with particularly high earthquake hazard, engineering seismology, and earthquake monitoring and information dissemination. In addition to supporting a broad range of technical expertise within the agency, the USGS has been committed to distributing approximately 25 percent of its earthquake program funds to studies proposed and conducted by organizations external to the Federal Government, such as State and local governments, universities, and private industry.

A goal of the USGS Earthquake Hazards Program is to quantify the earthquake hazard for various regions of the country in order to answer questions such as:

- Where do we expect the earthquakes to occur?
- How large will they be?
- How frequently will they occur?
- How strongly will the ground shake?
- What effects will result from the shaking?
- When will the next large earthquake occur?

Because there is, of course, a limit to the resources available to answer these questions, we cannot simultaneously address these concerns across the Nation. In determining where to focus USGS efforts, we have factored together two fundamental criteria:

- the seriousness of the earthquake hazard for a given region, and
- the level of population and investment at risk in that region.

To date, these factors have led to the strategy that northern and southern California, having a high earthquake hazard and large population base at risk, must have the largest single focus of effort, and this need will undoubtedly continue through the next decade.

In addition, the USGS has endeavored to give attention to other geographic regions of high risk. For several years, the Wasatch fault zone of Utah had such a focus, and we have been quite successful in providing a far better understanding of the Utah earthquake hazard. In addition, the USGS has cooperated with FEMA and is having an impact on the public awareness and preparedness for large earthquakes in that region.

For the past 2 years, the USGS has focused resources on the serious earthquake hazard questions of the Pacific Northwest, which includes much of western Washington and Oregon.

Based on the recorded history of the earthquakes of 1811-1812, the New Madrid seismic zone of the Central United States (see Attachment 2) appears capable of producing destructive earthquakes that could affect the entire midcontinent, from the Great Lakes to the Gulf of Mexico. The USGS has been, for several years, supporting earthquake research in the New Madrid seismic zone. Recently, with the special one-time FY 1990 appropriation from Congress following the Loma Prieta earthquake, we have begun a more concentrated effort on the New Madrid zone.

I would like to offer a few comments about the status of earthquake prediction. Although we have not yet reached the point where we are able to make short-term predictions of earthquakes, we are rapidly improving our ability to make probability forecasts for destructive earthquakes. This evolving capability to make quantified assessments of the space-time-magnitude characteristics of particular earthquake zones is proving to be of great value to State and local governments as well as private industry. Our ability to make such estimates is best in California where we have focused our energies over the past 10 years. However, for other regions of our Nation, we are presently unable to give satisfactory estimates regarding the frequency of events in the past, much less forecasts of how soon these events may recur in the future.

Nevertheless, the situation is optimistic; the USGS is continually making major strides in improving our understanding of the earthquake risk throughout the Nation. We do know many of the characteristics of earthquakes that have affected particular geographic regions in the past. In addition, our studies of current seismicity provide us with insights into the way that larger earthquakes can be expected to occur and how the geologic conditions and manmade structures are most likely to behave as a result of those events. We are carefully examining, for example, how the variations in local geology cause ground shaking to be amplified and what level of ground acceleration is necessary to induce the ground to liquefy, which together caused most of the casualties and economic loss in the recent Loma Prieta earthquake.

In conclusion, the USGS values the guidance and suggestions of this subcommittee as to how we can better serve the needs of the Nation. Although we can point to major gains that have occurred as a direct result of the NEHRP, there is still much to be accomplished; and we look forward to a significant continued role in this very important program.

This concludes my prepared statement; I will be pleased to answer any questions the subcommittee might have.

Senator Gore. Thank you very much.

Dr. Hays.

STATEMENT OF DR. JAMES F. HAYS, DIRECTOR, EARTH SCIENCES DIVISION, DIRECTORATE FOR GEOSCIENCES, NATIONAL SCIENCE FOUNDATION

Dr. Hays. Thank you, Mr. Chairman.

The National Science Foundation's contributions to NEHRP are in two parts of the Foundation, the Geosciences Directorate and the Engineering Directorate. I will speak to the geosciences work, and Dr. Hanson will talk about the engineering work.

The Division of Earth Sciences, which I head, is responsible for funding basic geological sciences research in U.S. colleges and universities. In 1990 the funding for this will amount to just over $60 million. $10 million of that, about 16 percent, will go to projects that relate directly to the understanding of earthquakes,—where and why they occur, and how to reduce their damaging effects.

These projects represent the fundamental earthquake studies component of NEHRP. They provide the scientific foundation for the more focused programs in hazard assessment and earthquake prediction under USGS, and I would like to say that the funds available to this program this year include $1 million in response to the Loma Prieta event. I would add my thanks to the other agencies for this.

I would like to take a few minutes to describe how we are handling those special Loma Prieta funds.

We received word on October 26 of the funds appropriated. Within a day or two we were consulting the other NEHRP agencies, and by November 13th we had drafted, cleared, issued, and distributed a special program announcement inviting proposals for Loma Prieta post-earthquake research. This program announcement was issued jointly with the USGS. It included engineering, social and economic aspects as well as geosciences. Proposals were received by November 28, jointly evaluated by December 9th, and successful proposers were notified of their awards by December 18th.

As early as October 18th, the day following the earthquake, researchers were given verbal authorization for field work to be funded through supplements to existing grants or through the Foundation's new program of Small Grants for Exploratory Research.

This was not, however, our first involvement with Loma Prieta. As early as 1984 Professor Lynn Sykes of Columbia University published a paper identifying the Loma Prieta segment of the San Andreas Fault as one of the two most likely sites for a large earthquake to occur. Based on two seismic events in the summers of '88 and '89 which we now recognize as preshocks for Loma Prieta. Professor Karen McNally of the University of California at Santa Cruz moved an array of seismic instruments into the area that later proved to be the epicentral region of the October 17th earthquake. Both Sykes and McNally were funded under the fundamental earthquake studies element.

Within minutes after the October 17th event, seismologists around the world were able to obtain digital seismometer records of the event by computer dial-in to two of the new generation of global seismic network stations funded by the Foundation through the IRIS university consortium.

The complete seismic moment tensor and mechanism of the earthquake was known within a few hours. When the NEHRP program began, this was something that ordinarily would have taken months.

Within hours of the earthquake GPS geodetic instruments funded by the Foundation through the UNAVCO consortium were able to determine the displacement along the fault where direct geological observations had been confusing. That was done jointly with the staff of USGS.

Portable seismometers from the PASCAL portable seismic array, also developed by IRIS and funded by the Foundation, were used to study the many aftershocks and to make important engineering observations on the collapsed Nimitz Freeway. IRIS worked jointly with the National Center for Earthquake Engineering Research.

This comprehensive response carried out with full coordination among the other NEHRP agencies was possible only because of several years of seismic instrument development and acquisition funded by the fundamental earthquake studies element of NEHRP. This continues to be one of the major thrusts of our program.

Other high priority areas for basic research include intra-plate earthquakes of the kind that Senator Gore mentioned, earthquake source theory, direct measurement of crustal stress and deformation and studies of seismically active geological structures.

Research grants for fundamental earthquake research have gone to more than half of the 50 states during the past five years, and there are several examples in the written statement. I want to stress here that all of the foundation's activities in fundamental earthquake studies are carried out in close coordination with the USGS and the other NEHRP agencies.

Dr. Whitcomb, who heads this program, participates in USGS planning workshops and proposal review panels. His counterpart in the USGS sits in on the NSF review panels. Program announcements have been issued jointly, and many of the projects, including IRIS and the Cajon Pass Drilling project, involve direct collaboration with the USGS personnel and their university-funded investigators.

Finally, I would like to close by saying that it is often basic research in unexpected areas that will open the door to new ideas for earthquake hazard assessments and earthquake prediction. If we do not do enough of that or if we confine our research efforts too narrowly, we may miss just the breakthrough we need to make important progress.

I believe that a broadly based innovative program of fundamental earthquake studies is an essential and productive element of the National Earthquake Hazard Reduction Program. Thank you.

[The statement follows:]

TESTIMONY BEFORE THE SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE OF THE SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

MARCH 29, 1990

by Dr. James F. Hays
Division Director, Division of Earth Sciences
National Science Foundation

Mr. Chairman and members of the Subcommittee:

The National Science Foundation's Division of Earth Sciences provides funding support through grants and cooperative agreements to U.S. universities, colleges, and university consortia for basic research in all aspects of the geological sciences. In 1990 this support will amount to just over $60 million. Of this funding support, approximately 16 percent--$10 million--goes to projects that relate directly to the understanding of earthquake occurrences and the mitigation of their damaging effects. These projects represent the Fundamental Earthquake Studies component of the National Earthquake Hazard Reduction Program (NEHRP), and provide the theoretical, experimental, and observational underpinning for the more focussed programs in hazard assessment and earthquake prediction funded by the U.S. Geological Survey (USGS).

Funds available to this program during the current year include $1 million transferred to the Foundation under Public Law 101-130 for earthquake-related research in response to the Loma Prieta Earthquake of October 17, 1989.

In the early years of NEHRP, proposals for earthquake research responded to the general Earth Sciences program announcement, and were treated as competitive with all other proposals received by the Division of Earth Sciences. The amounts reported as NEHRP funding by the Foundation reflected only the relative success of earthquake-related proposals in the merit review competition.

As the NEHRP has evolved into a more focussed program, the Fundamental Earthquake Studies component has changed to reflect this. The program is now headed by Dr. James Whitcomb, a recognized earthquake specialist and a member of the Foundation's staff. The Foundation has issued two special program announcements in this area outlining problems where research is especially needed, and another such announcement will be issued next month. The Foundation's Budget Request and Current Plan clearly state the anticipated funding levels for NEHRP, and in the merit review of proposals competing for these funds, 'potential for contribution to the goals of NEHRP' is now an explicit criterion.

I want to take a few minutes to describe our handling of the special Loma Prieta funds, and to describe some of the ways that a basic research program in seismology and earth sciences can contribute significantly to the goals of NEHRP.

We received word on October 26 of the supplemental funds appropriated to the President for earthquake-related activities under Public Law 101-130. Anticipating additional research funds we consulted with the other NEHRP agencies and by November 13 had drafted, cleared, issued, and distributed a special program announcement inviting proposals for Loma Prieta post-earthquake research. This program announcement was issued jointly with the USGS and included engineering, social, and economic aspects, as well as geosciences. Funds were transferred to the Foundation by the President on November 21. Proposals were received by November 28, jointly evaluated by December 9, and successful proposers were notified of their awards by December 18. As early as October 18--the day following the earthquake--researchers were given verbal authorization for field work to be funded through supplements to existing grants or through the Foundation's new program of Small Grants for Exploratory Research.

In 1984, Professor Lynn Sykes of Columbia University, funded through the Fundamental Earthquake Studies element of NEHRP, published a paper identifying the Loma Prieta segment of the San Andreas Fault as one of the two most likely sites for a large earthquake to occur. Based on two seismic events in the summers of 1988 and 1989--now recognized as Loma Prieta preshocks--Professor Karen McNally of the University of California at Santa Cruz, also funded by the Fundamental Earthquake Studies element of NEHRP, moved an array of seismic instruments into the area that later proved to be the epicentral region of the October 17 earthquake. Within minutes after the Loma Prieta event seismologists around the world were able to obtain digital seismometer records of the event by computer dial-in to two of the new generation of Global Seismic Network stations funded by the Foundation through the IRIS university consortium. The complete seismic moment-tensor of the earthquake was known within a few hours. In the days following the earthquake, GPS geodetic instruments, funded by the Foundation through the UNAVCO consortium, were able to determine the displacement along the fault where direct geological observations had been confusing. Portable seismometers from the PASSCAL Portable Seismic Array, also developed by IRIS and funded by the Foundation, were used to study the many aftershocks and to make important engineering observations on the collapsed Nimitz Freeway.

This comprehensive response--carried out in full coordination with the other NEHRP agencies--was possible only because of several years of seismic instrument development and acquisition funded by the Fundamental Earthquake Studies element of NEHRP. This continues to be one of the major thrusts of our program.
Other high priority areas for basic research include: intraplate earthquakes, earthquake source theory, direct measurement of

crustal stress and deformation, and studies of seismically active geological structures.

Research grants for fundamental earthquake research have gone to more than half of the 50 states during the past five years. These include, of course, a number of research projects in California. But research expertise and earthquake hazard are widely distributed in the U.S.

For example, the Pacific Northwest has been long identified as a subduction-type plate boundary like those that occur in seismically active zones of South America, Japan and Alaska. Seismic studies of the subducting slab underneath the Pacific Northwest are difficult to do because of the extensive surface volcanic flows that mask the deep structure from seismic wave penetration. However, a different geophysical method using natural electromagnetic waves was funded by NSF in cooperation with university and government institutions from Canada, Japan, Mexico and Australia. Electromagnetic sounding revealed the subducting slab geometry with surprising success. This has led to a renewal of seismic profiling that is tuned to the structure already found. These studies are an integral part of a multiple U.S. agency effort to determine the seismic hazard in the Pacific Northwest.

The New Madrid region in the midwest experienced great earthquakes in 1811-1812. NSF has supported major seismic reflection and refraction studies in and near this zone by the COCORP group from Cornell University and later by the IRIS university consortium. The structure responsible for the earthquakes has been identified as a reactivated Mesozoic rift of the continental plate. However, the forces that have brought about renewed distortion of the rift structure are still poorly understood.

Another project of special interest to residents of Southern California--but important to everyone living near a major fault anywhere in world--is the Cajon Pass Drilling Project. Using Fundamental Earthquake Studies funds, a hole was drilled to a depth of 3.5 km just 4.3 km away from the San Andreas Fault near San Bernardino, California. Measurements of stress within the earth's crust and the rate of flow of heat from the earth's interior made within this drillhole, have confirmed a controversial hypothesis that shearing stresses along the fault are much weaker than had been predicted from laboratory studies. This discrepancy--not yet fully understood--is likely to alter our ideas of fault mechanics and may effect our assessments of earthquake probabilities. The USGS plans to use this hole as a deep seismic observatory near the fault.

All of the Foundation's activities in Fundamental Earthquake Studies are carried out in close coordination with the USGS. Dr. Whitcomb participates in USGS planning workshops and proposal review panels; USGS officials participate in NSF proposal reviews; program announcements have been issued jointly; and many NSF-funded projects--including IRIS and Cajon Pass--involve direct collaboration with USGS personnel or USGS-funded university investigators.

Finally, I would comment that it is basic research--often in unexpected areas--that will open the door to new ideas for earthquake hazard assessments and earthquake prediction. If we confine our research efforts too narrowly, we may miss precisely the breakthrough needed to make important progress. I believe that a broadly based, innovative, program of Fundamental Earthquake Studies is an essential and productive element of the National Earthquake Hazard Reduction Program.

I would be happy to answer any questions you might have.

Senator **Gore**. Thank you very much.

Dr. Hanson.

STATEMENT OF DR. ROBERT D. HANSON, DIRECTOR, BIOLOGICAL AND CRITICAL SYSTEMS DIVISION, ENGINEERING DIRECTORATE, SCIENCE FOUNDATION

Dr. **Hanson**. Thank you, Mr. Chairman and members of the subcommittee, Senator Gorton.

The Earthquake hazard mitigation research program in engineering at the National Science Foundation supports fundamental investigations in engineering and the social sciences directed toward mitigating the effects of earthquakes. The goal is to strengthen the existing knowledge base in earthquake engineering and related disciplines in order to minimize the loss of life and resources due to earthquakes.

The NSF earthquake engineering research budget for fiscal year 1990 current plan is $14.3 million plus the $2 million transferred pursuant to Public Law 101-130. The NSF FY 1991 budget request for earthquake engineering research is $15.2 million.

It is important to note that earthquake engineering research conducted with NSF funds are performed by researchers and practitioners in the academic, research and business community and not by the four professional NSF staff members. This research has broad-based applications and can generally be directed toward earthquake hazard mitigation efforts throughout the United States.

NSF has actively supported post-earthquake investigations for over 15 years. Thus, we have been able to capture the experiences from many damaging earthquakes, most recent examples of which include Mexico in 1985, Chile in 1985, Whittier, California, in 1987, Armenia in 1988, and Loma Prieta in 1989.

When appropriate, these field investigations are followed by intensive research studies to determine the characteristics of the earthquake ground motion, the performance of buildings and lifelines to those ground motions, the type of damage and the relationship of actual performance and damage to that predicted from analytical and laboratory experimental studies, and the institutional responses to the event.

In the case of the Loma Prieta earthquake, major research efforts are being made to understand the characteristics of soft ground and its influence on building and lifeline response, a correlation of building code design and building damage, performance of strengthened buildings, the implications of local mitigation programs, cause and effects of the fires, the relationship of earthquake-caused injuries and death as they are related to building damage, and the short-term effect of the earthquake on the homeless, the low income, the elderly, and non-English speaking people.

As Dr. Hays indicated, NSF and USGS have initiated a joint research program on the Loma Prieta earthquake. Of the $8 million transferred to USGS for post-earthquake investigations by Public Law 101-130, USGS has transferred $1.5 million to NSF engineering for support of Loma Prieta post-earthquake engineering investigations.

In addition, NSF engineering has funded $1.2 million in quick response collection of perishable data and first round engineering research investigations of Loma Prieta earthquake which were not covered by the USGS funds.

NSF engineering also expects to fund approximately $1.5 million for the second round of USGS/NSF joint research program. Thus, about $2.7 million of NSF engineering funds will be used for the Loma Prieta earthquake investigations while $2 million of supplemental appropriations was transferred to NSF engineering pursuant to Public Law 101-130.

We sincerely appreciate and thank you, Senator Gore, for your leadership and the members of this subcommittee for their support of the supplemental appropriation.

There is much to be learned from the Loma Prieta experience. Some of the most apparent lessons reinforce the lessons that were learned from earlier earthquakes. Yet, there are other lessons which will not be understood until the results of these funded research investigations are completed.

Even though all the lessons are not yet learned, those that have been relearned should be put into practice now. It is important for all cities subjected to earthquake risk to take positive action to ensure the safety of their citizens.

Recent earthquakes have demonstrated that manmade systems designed and constructed in accordance with current earthquake resistant knowledge and techniques have not collapsed, while systems designed without earthquake considerations or constructed without compliance with special earthquake-resistant details have resulted in major loss of life and major damage.

These earthquakes have also demonstrated that buildings can perform so well that owners are now demanding that their buildings not only provide life safety, but control the earthquake damage and provide continued functional operation as well. New buildings can be designed for this improved performance with a reasonable increase in cost.

The biggest problem is posed by existing manmade systems that have not been designed for earthquakes or designed to earthquake criteria which are now recognized as being inadequate for life safety.

These vulnerable manmade systems are located throughout the United States, even in California. It is physically and economically impossible to upgrade all vulnerable systems throughout the U.S. before the next earthquake occurs. We must spend our resources in the most efficient manner possible to achieve the greatest benefit for our citizens.

How can this be accomplished? One, the seismic risk of cities must be assessed with a view toward upgrading constructed systems as appropriate. Two, techniques for accurate assessment of earthquake resistance of constructed systems must be established. Three, economical and effective techniques for upgrading must be established and implemented. Four, a priority for upgrading must be established and implemented. And, five, high risk communities should be encouraged to develop effective earthquake preparedness plans.

The earthquake research program at NSF has made major contributions toward the goal of reducing loss of lives and resources from earthquakes. Future plans continue to be aimed at changing technologies and changing user needs.

NSF will continue to disseminate research results to users and cooperate with other relevant agencies in such activities. Our dissemination efforts are aimed at a diverse audience including engineers, architects, building officials, government decision makers and researchers.

Numerous channels of communication are used to inform users of relevant research results. Central to our dissemination program are the National Information Service for Earthquake Engineering at the University of California-Berkeley, and at the California Institute of Technology; the National Hazards Information Center at the University of Colorado; and the information service at the National Center for Earthquake Engineering Research at SUNY-Buffalo.

NSF encourages its grantees to work directly with government and building code officials. Researchers at NCEER have been particularly successful recently in encouraging officials in such locations as New York City and the State of Connecticut to give attention to seismic issues.

One of the primary missions of NSF is to facilitate the education of the next generation of scientists and engineers. Perhaps the best implementation mechanisms we have, then, are those students who become professionals after participating in NSF-sponsored projects. This group of trained professionals is a key to implementation because they put into practice the knowledge on earthquake hazards that they learned as students in the field, laboratory and classroom.

We support the attention given to research, implementation and application in the reauthorization legislation. As I have noted, NSF is committed to implementation as demonstrated by our efforts in this area. However, much research in the multiple disciplines relevant to earthquake hazard mitigation remains to be done and, therefore, increased implementation should not come at the expense of future research.

Let me also say in closing that NSF has worked well with all of the principal NEHRP agencies, and we look forward to our continued cooperation with them. I will be pleased to answer any questions that the subcommittee may have.

Thank you, Dr. Hanson.

Dr. Wright.

STATEMENT OF RICHARD N. WRIGHT, DIRECTOR, CENTER FOR BUILDING TECHNOLOGY, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Dr. **Wright**. Thank you, Mr. Chairman, and members of the committee. Dr. Lyons asked me to express his regrets that he could not present our statement. He is testifying before your subcommittee on appropriations.

In the National Earthquake Hazards Reduction Program the National Institute of Standards and Technology provides research and technical support for the development and application of improved seismic design and construction practices.

NIST conducts research to obtain needed knowledge using its laboratory and computational facilities, provides technical support to private and governmental organizations for the development and application of improved practices, and conducts post-earthquake investigations to ascertain the effectiveness of design and construction practices in real earthquakes.

Our statement for the record describes accomplishments and activities within the NEHRP to improve and apply seismic design and construction practices for federal agencies, the private sector, and state and local governments.

It describes findings of the investigation conducted by the Interagency Committee on Seismic Safety and Construction, and NIST, following the Loma Prieta, California, earthquake. And it describes NIST's research and technology transfer efforts for the NEHRP.

I will summarize this very briefly.

At the beginning of the NEHRP, the Federal Emergency Management Agency and NIST initiated programs to improve the seismic design and construction practices of the federal agencies, the private sector, and state and local governments.

The Interagency Committee on Seismic Safety and Construction was established to assist federal departments and agencies involved in construction to develop earthquake hazard reduction practices for incorporation in their ongoing programs.

The Building Seismic Safety Council was established as an independent voluntary body, representing the full spectrum of building community interests, and providing a national forum to foster improved seismic safety provisions for use in planning, design, construction and regulation of buildings.

Close liaison has been maintained between the Building Seismic Safety Council and the Interagency Committee activities, with the Interagency Committee providing a member of the Building Seismic Safety Council's board, and participating in the Building Seismic Safety Council's technical committees.

Twenty-five federal departments and independent agencies with responsibilities for design, construction or operation of buildings or lifelines, or for assistance or regulation of these activities, are members of the Interagency Committee. The committee uses consensus procedures to recommend earthquake hazard reduction practices suitable for use for the federal agencies.

The committee is accountable to FEMA, which provides financial support for the Interagency Committee secretariat. The committee has produced a number of technical reports and recommended practices, which are listed in our prepared testimony.

The implementation of the seismic safety practices remains a responsibility of the individual federal departments and independent agencies. To provide consistent authority and to set an example for emulation by the private sector and state and local governments, the Interagency Committee developed in 1986 a proposed executive order for the seismic safety of federal and federally assisted or regulated construction.

After formal processing and revisions, on January 5th, 1990, the President issued Executive Order 12699, Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction. The executive order requires appropriate seismic design and construction practices for new buildings constructed or leased for federal use, and within three years, requires that federally assisted or regulated new building construction use appropriate seismic design and construction practices.

The work of the Building Seismic Safety Council has progressed well with financial support from FEMA and technical support from NIST. The NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings have been developed by the Building Seismic Safety Council to provide the basis for the seismic safety requirements of building standards and codes used nationwide for design and construction.

Trial designs constructed by the Building Seismic Safety Council have shown that seismic safety in new buildings is achieved at costs averaging less than 2 percent of the construction costs. The major expense for seismic safety in new building construction is for education, for the owners, designers and builders to learn how to achieve seismic safety. Then, practices for seismic safety can be applied at little or no extra cost for design, construction and operation.

Earthquake catastrophes readily can be avoided for new buildings.

The Building Seismic Safety Council and model code organizations are working to incorporate NEHRP recommended provisions in the model building codes used in the eastern and central United States by 1992. Use of the present seismic provisions of these model building codes would substantially increase seismic safety. The model code used in the western United States already is equivalent to the NEHRP recommended provisions.

When nationally recognized standards and model codes are available and adequate for federal construction, it is more efficient to use them than to develop separate federal standards. Redundant standards development activities are avoided, and designers and builders can use familiar standards on federal projects.

Therefore, we support development of national voluntary standards and model codes appropriate to all construction, including private and state and local government facilities, rather than focusing solely on federal or federally assisted or regulated facilities.

This requires involvement of all concerned groups, and use of nationally recognized voluntary consensus standards procedures, but it leads to better quality standards and quicker acceptance for all construction.

This process has been proven in the development of the NEHRP Recommended Provisions and their subsequent use in national standards and model building codes. These national standards and model building codes will be used by the federal agencies in their implementation of the executive order.

Work currently underway by the Building Seismic Safety Council, funded by FEMA, and with technical support from NIST, will produce recommended practices for the assessment of the seismic hazards of existing buildings, and for strengthening buildings with inadequate resistance.

Work is not yet planned or underway to develop a complete and consistent family of standards for new and existing lifeline facilities. Lifelines are public works and utilities, transportation facilities, oil and gas pipelines, electrical power and communication facilities, water supply and sewage treatment facilities.

Some standards are available, for instance, for highways, bridges and for nuclear power facilities. However, further research is needed to assess knowledge from research and experience, and to formulate quantitative provisions for the design and construction of new lifelines in each category, to assess effectiveness and economy through trial designs, and recommend their adoption in national standards.

The damages in the Loma Prieta earthquake showed us the importance of lifeline safety, and it is desirable to push these activities ahead so that new and existing lifelines are adequate to resist the effects of earthquakes.

Our studies in the NEHRP and experiences in the Loma Prieta earthquake and prior earthquakes showed NIST that major engineering application and development and research efforts are needed to achieve seismic safety of buildings and lifelines. Application and development efforts to exploit and apply knowledge from research should be pursued vigorously in concert with a continued strong research effort.

The Loma Prieta earthquake struck the San Francisco Bay area at 5 p.m. on October 17th. Within a few hours the Interagency Committee on Seismic Safety and Construction decided to send an investigation team to the affected area the next day. On October 18th, your committee and the House subcommittee on science research and technology asked NIST to investigate earthquake damage, including the elevated section of Interstate 880, and other elevated highway and bridge structures.

The Interagency Committee team, including members from NIST, the Geological Survey, the Federal Highway Administration, and the Department of Housing and Urban Development, with assistance from FEMA, responded to your request.

Copies of our report have been made available to the committee. The conclusions and recommendations are included in our written testimony.

Public Law 101-130, with your help, Senator Gore, provided additional funding to the President for earthquake-related activities. The President allocated $2 million to NIST for investigations of structural performance in the Loma Prieta earthquake, and for research in earthquake hazard reduction.

The research activities we are conducting in response are listed in our prepared testimony. They are funded by the special funds from Public Law 101-130, by NIST base funding, and by funds transferred from the U.S. Geological Survey.

Each activity is aimed at gaining knowledge needed for prompt improvements in seismic design and construction practices.

Thank you for the opportunity to describe our work. I shall be happy to respond to any questions.

[The statement follows:]

NIST
UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY

STATEMENT OF RICHARD N. WRIGHT

DIRECTOR, CENTER FOR BUILDING TECHNOLOGY

BEFORE THE

SENATE COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE

HEARING ON REAUTHORIZATION FOR THE

NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

MARCH 29, 1990

INTRODUCTION

In the National Earthquake Hazards Reduction Program (NEHRP) the National Institute of Standards and Technology (NIST) provides research and technical support for the development of improved seismic design and construction practices. NIST conducts research to obtain needed knowledge using its unique laboratory and computational facilities, provides technical support to private and governmental organizations for the development and application of improved practices, and conducts post earthquake investigations to ascertain the effectiveness of design and construction practices in real earthquakes.

NIST is working actively with other Federal agencies, other research organizations, and professional and technical organizations of the building community, worldwide, to develop and implement improved seismic design and construction practices that will be cost effective for dealing with the earthquake threat in the United States.

We support reauthorization of the National Earthquake Hazards Reduction Program at levels requested in the President's Budget for FY 1991. The request for NIST is $525,000 for responsibilities under the Act.

This statement describes:

1. NEHRP accomplishments and activities to improve and apply seismic design and construction practices for Federal agencies, the private

sector and state and local governments.

2. Findings of the investigation conducted by the Interagency Committee on Seismic Safety in Construction (ICSSC) and NIST following the Loma Prieta, California earthquake of October 17, 1989.

3. NIST research and technology transfer for the NEHRP.

NEHRP EFFORTS TO IMPROVE SEISMIC DESIGN AND CONSTRUCTION PRACTICES

At the beginning of the NEHRP, the Federal Emergency Management Agency (FEMA) and NIST initiated programs to improve the seismic design and construction practices of the Federal agencies, the private sector and state and local governments. The Interagency Committee on Seismic Safety in Construction (ICSSC) was established to assist Federal departments and agencies involved in construction to develop earthquake hazard reduction practices for incorporation in their ongoing programs. The Building Seismic Safety Council (BSSC) was established as an independent, voluntary body representing the full spectrum of building community interests and providing a national forum to foster improved seismic safety provisions for use in planning, design, construction, regulation and use of buildings.

Close liaison has been maintained between BSSC and ICSSC with ICSSC providing a member of BSSC's Board and participating in BSSC's technical committees.

Twenty-five Federal departments and independent agencies with responsibilities for design, construction or operation of buildings or lifelines, or for assistance or regulation of these activities, are members of ICSSC. ICSSC uses consensus procedures to recommend earthquake hazard reduction practices suitable for use by Federal agencies. Each Federal agency may adopt these recommendations, or modifications thereof, as required practices through the use of established Federal procedures for implementing regulations. ICSSC is accountable to FEMA which provides financial support for the ICSSC secretariat. NIST provides the chairman of ICSSC.

The technical activities of ICSSC are conducted by five subcommittees:

1. Standards for New and Existing Buildings

2. Lifelines

3. Evaluation of Site Hazards

4. Federal Domestic Assistance, Leasing and Regulatory Programs

5. Post Earthquake Response

ICSSC produces technical reports (TR) and recommended practices (RP) for use by Federal agencies:

TR 1, "Draft Seismic Standard for Federal Buildings," 1981.

TR 2, "Evaluation of Potential Surface Faulting and Other Tectonic Deformation," 1982.

TR 3, "Evaluation of Earthquake-Induced Ground Failure," 1982.

TR 4, "Considerations in Selecting Earthquake Motions for the Engineering Design of Large Dams," 1983.

TR 5, "Guidelines for ICSSC Post-Earthquake Response Activities," 1985.

TR 6, "An Introduction to Technical Issues in the Evaluation of Seismic Hazards for Earthquake-Resistant Design," 1985.

TR 8, "Tsunamis - Hazard Definition and Effects on Facilities," 1985.

TR 9, "Workshops Convened by the Interagency Committee on Seismic Safety in Construction in 1984," 1985.

TR 10, "A Review of Information on Seismic Hazards Needed for Earthquake-Resistant Design of Lifeline Systems in the United States," 1988.

TR 11, "Performance of Structures During the Loma Prieta Earthquake of October 17, 1989," 1990.

RP 1, "Seismic Design Guidelines for Federal Buildings," 1987.

RP 2, "Guidelines and Procedures for Implementation of the Executive Order on Seismic Safety," 1988.

RP 3, "Guidelines for Identification and Mitigation of Seismically Hazardous Existing Federal Buildings," 1989.

The implementation of seismic safety practices remains a responsibility of the individual Federal departments and independent agencies. To provide consistent authority, and to set an example for emulation by the private sector and state and local governments, ICSSC developed in 1986 a proposed executive order "Seismic Safety of Federal and Federally Assisted or Regulated Construction." After formal processing and revisions, on January 5, 1990, the President issued Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction." The Executive Order requires appropriate seismic design and construction practices for new buildings constructed or lease-constructed for Federal use, and within three years requires that Federally assisted or regulated new building construction use appropriate seismic design and construction practices.

Work of the BSSC has progressed well with financial support from FEMA and technical support from NIST. The NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings have been developed by BSSC to provide the basis for the seismic safety requirements of building standards and codes used nationwide for design and construction. The Recommended Provisions incorporate probability-based seismic hazard maps, developed by the U.S. Geological Survey (USGS), to account rationally for the differences in seismic hazards in various parts of the Nation, and to reveal to decision makers the variation within the United States of earthquake intensity with exposure time. The Recommended Provisions also are based substantially on research and technical studies sponsored by the National Science Foundation (NSF).

Trial designs conducted by BSSC have shown that seismic safety in new buildings is achieved at costs averaging less than 2 percent of construction cost. The major expense for seismic safety in new building construction is for education: for owners, designers and builders to learn how to achieve seismic safety. Then practices for seismic safety can be applied at little or no extra cost for design, construction, or operation. Earthquake catastrophes readily can be avoided for new buildings.

The BSSC and model code organizations are working to incorporate NEHRP Recommended Provisions in the model building codes used in the Eastern and Central United States in 1992. Use of the present seismic provisions of these model building codes would substantially increase seismic safety. The model code used in the Western United States already is equivalent to the NEHRP Recommended Provisions. Federal guidelines [1,2] are available to assist owners and designers to incorporate seismic provisions when they are lacking from local building codes.

With financial support from FEMA and NSF, and technical support from NIST, the Applied Technology Council (ATC) and BSSC are developing and disseminating nationally applicable practices for assessment of seismic hazards of existing buildings and strengthening of those unduly hazardous. Useful practices are available [3], and work underway will augment them. Costs of strengthening are highly variable, dependent on the specific properties of the existing building and site. However, the cost, ranging from $4-13 per square foot [4], is not large compared to normal costs for cosmetic or functional renovations.

When nationally-recognized standards and model codes are available and adequate for Federal construction, it is more efficient to use them than to develop Federal standards. Redundant standards development activities are avoided and designers and builders can use familiar standards on Federal projects. Therefore, we support development of national voluntary standards and model codes appropriate to all construction, including private and state and local government facilities, rather than focusing solely on Federal or Federally assisted or regulated facilities. This requires involvement of all concerned groups and use of nationally-recognized, voluntary, consensus standards procedures, but leads to better quality standards and quicker acceptance for all construction. This process has been proven in development of the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings, and their subsequent use in national standards and model building codes. These national standards and model codes will be used by the Federal agencies in their implementation of Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction."

Work currently underway by BSSC, funded by FEMA and with technical support from NIST, will produce recommended practices (1) for the assessment of seismic hazards of existing buildings, and (2) for strengthening buildings with inadequate resistance. We expect that these will be available for Federal agencies' use by June 1, 1993. Agencies could begin programs to assess their existing buildings and to correct those unduly hazardous. However, studies to assess cost implications, to determine responsible and cost effective resistance levels for strengthening (the shorter lifetime of an existing building, and greater costs of retrofit than new construction, may justify lesser resistance than that required for a new building), and to incorporate recommended practices in national standards and model codes will not be complete by June 1, 1993.

Work is not yet planned or underway to develop a complete and consistent family of standards for new and existing lifeline facilities. Lifelines are public works and utilities: transportation facilities, oil and gas pipelines, electrical power and communication facilities, and water supply and sewage treatment facilities. Some standards are available, for instance for highway bridges and for nuclear power facilities. The American Society of Civil Engineers' Technical Council on Lifeline Earthquake Engineering, with sponsorship by NSF, has conducted valuable studies in each of the categories. However, further research could be undertaken to assess knowledge from research and experience and formulate quantitative provisions for the design and construction of new lifelines in each category, assess effectiveness and economy through trial designs, and recommend their adoption in national standards. Additional efforts could then be focused on developing standards for the assessment of the seismic safety of existing lifelines and the correction of those found to be unduly hazardous. Thus, conduct of additional research and development effort [5,6] could lead to effective practices for the seismic safety of new and existing lifelines.

To summarize briefly, studies in the NEHRP and experiences in the Loma Prieta, California, earthquake of October 17, 1989, and prior earthquakes show NIST that the major engineering application, development and research efforts needed to achieve seismic safety of buildings and lifelines are:

- Application of Seismic Safety Practices
  - Incorporate knowledge in standards, practices and regulations.
  - Educate owners, designers, builders, regulators and the public to use available practices.
  - Adopt and enforce up-to-date standards and codes for buildings, lifelines and land use.

  - Conduct systematic programs to assess seismic resistance of existing buildings and lifelines and correct those that are unduly hazardous.
  - Incorporate mitigation provisions in earthquake insurance.

- Development of Improved Seismic Safety Practices
  - Seismic design and construction provisions for lifelines.
  - Assessment of seismic safety of existing buildings and lifelines.
  - Cost-effective strengthening of existing buildings and lifelines.
  - Safe, cost-effective practices for innovative structural systems and materials.
  - Site hazards assessment and abatement.

- Research for Improvement of Seismic Safety Practices
  - Site-specific definition of seismic loads.
  - Soil-foundation-structure interaction.
  - Changes of strength and stiffness with inelastic response to earthquake motions.
  - Residual strength and energy absorbing capacity of "damaged" structures.
  - Reliable, appropriate technologies for base isolation, energy absorption and control of structures.
  - Seismic behavior of innovative structures, systems and materials.

These are stated in this unusual order to emphasize that application and development efforts to exploit and apply existing knowledge from research should be pursued vigorously in concert with a continued, strong research effort.

NIST ACTIVITIES FOLLOWING THE LOMA PRIETA EARTHQUAKE

The Loma Prieta earthquake struck the San Francisco Bay region at 5:04 p.m. (PDT) on October 17, 1989. Within a few hours, the Interagency Committee on Seismic Safety in Construction (ICSSC), which NIST chairs, decided to send an investigation team to the affected area on October 18, 1989. On October 18, 1989, your Committee and the House Committee on Science, Space, and Technology, Subcommittee on Science, Research, and Technology asked NIST to investigate earthquake damage including the elevated section of Interstate 880 and other elevated highway and bridge structures. The ICSSC team, including members from NIST, the United

States Geological Survey, the Federal Highway Administration, and the Department of Housing and Urban Development with assistance from the Federal Emergency Management Agency, responded to your request. Funding for the investigation has been provided by the U.S. Geological Survey using the P.L. 101-130 appropriation.

Our report, "Performance of Structures During the Loma Prieta Earthquake of October 17, 1989," copies of which we offer for the Committee's use, has been prepared in partial response to your request. The report represents a working document of the Interagency Committee on Seismic Safety in Construction which will be used as a basis for ongoing discussions in program development. Conclusions and recommendations from the report, which represents the views of the Interagency Committee on Seismic Safety in Construction, are as follows:

> Conclusions
>
> The Loma Prieta earthquake of October 17, 1989, can provide significant lessons for public policies and construction practices throughout the United States. While it was the largest earthquake to strike Northern California since the great San Francisco earthquake of 1906, earthquakes of similar or larger size are expected to affect 46 of the 50 states, Puerto Rico and the Virgin Islands (Federal Emergency Management Agency, 1988). Thus, lessons of structural performance and seismology, which can be learned from the Loma Prieta earthquake, can be used to reduce earthquake hazards throughout the United States and the rest of the world.
>
> Performance of All Structures
>
> 1. The Loma Prieta earthquake caused substantial human losses of 62 lives and 3,757 injuries. But for fortunate circumstances, human losses would have been much greater. The unusual event of coincidence with a Bay Area World Series baseball game reduced traffic far below normal levels on the I-880 viaduct which collapsed to cause most of the life losses. Although water supplies for fire fighting were lost over much of the Bay Area, unusually calm winds avoided uncontrolled spreading of fires. The areas affected by the earthquake are among the few best prepared in the United States. Clearly, earthquakes remain the United States' greatest single-event natural hazard threatening losses of life and injuries.
>
> 2. Direct property losses are estimated to exceed $6 billion, but these are modest compared to losses projected for earthquakes closer to major metropolitan areas, for instance $40 billion for a magnitude 7.5 earthquake on the Eastern Bay Area's Hayward Fault, (California Department of Conservation, 1987) or $37 billion for a magnitude 7.6 earthquake in the New Madrid area of the Central U.S. (Allen and Hoshall, 1985). Unless actions are taken to reduce earthquake hazards, nationwide, earthquake property losses can be sufficiently large to seriously impact the U.S. economy

(The Earthquake Project, 1989).

3. Consequent economic losses were apparent in the major disruptions of transportation in the month that the San Francisco - Oakland Bay Bridge was out of service. Dislocations continue with major segments of the Bay Area highway system still not functioning. The potential for consequent economic, national security and societal losses arising from earthquake damages add to the status of earthquakes as the Nation's greatest single-event natural hazard.

4. Most building and lifeline structures in the epicentral and Bay areas performed well. Californian efforts to develop, adopt and enforce up to date seismic design and construction practices for buildings and lifelines deserve great credit for this. However, much structural damage and most losses of lives and property occurred in the Bay Area far from the earthquake faulting. At such distances, for this sized earthquake, current seismic design and construction practices were considered to be capable of preventing structural damages. Thus, the seismology and structural performance in the Loma Prieta earthquake provide important opportunities for the assessment and improvement of national seismic design and construction practices.

5. Most structural damages in the Bay Area, 50 to 70 miles from the epicentral area, occurred to structures sited on deep deposits of overburden soils above the bedrock. Such sites are common in other areas of the Nation that also are subject to earthquake hazards. Also, the intensity of bedrock ground shaking was much higher in the Bay Area than in other directions from the epicentral area. Because many records of strong ground motions are available from the main shock and aftershock measurements, there are important opportunities to develop and verify seismological and engineering practices for prediction of the effects of geological and overburden soil conditions on the intensity of earthquake ground motions.

6. Structural damages and failures in both epicentral and Bay areas indicate some vulnerability for structures with natural periods less than that of their sites. Indepth studies of responses of damaged and undamaged structures can assess the needs, if any, for revisions of current seismic standards which allow reduced design forces for structures of low natural period sited on deep, soft soil deposits.

7. Ground failures, including landslides and liquefaction, were frequent in both epicentral and Bay areas. These attest to the potential of ground failures to produce earthquake losses of lives and property and provide opportunities to assess the needs to improve existing criteria for the stability of soils in earthquakes.

Buildings Performance

1. Buildings designed and constructed in accord with modern seismic design and construction practices generally performed well in both epicentral and Bay areas. This shows the value of adopting and enforcing modern seismic design and construction practices in building codes and for Federal construction. However, examples of successful performance in areas of strong shaking and of failures in areas of moderate shaking provide opportunities to assess needs to improve modern seismic design and construction practices.

2. Widespread failures of older buildings, such as collapses of unreinforced masonry buildings, failures of cripple stud walls, and losses of chimneys and parapets, reemphasize the needs to assess the safety of existing buildings and to correct excessive hazards. It is sobering to note that many modern buildings also have these vulnerabilities in seismically hazardous areas of the U.S. which have not yet, or only recently have, adopted and enforced seismic design and construction provisions in their building codes.

3. Many older buildings in the epicentral and Bay areas had been retrofit to improve seismic resistance prior to the earthquake. Some performed well; some failed. Indepth studies of the performance of retrofit measures can reveal opportunities to affirm or to improve standards for assessment and strengthening of existing buildings that currently are being developed.

4. Many buildings in urban areas were damaged by pounding against adjacent buildings. Indepth studies of occurrences and non-occurrences of pounding can provide improvements, where needed, in standards for design of new buildings, and in standards for assessment and strengthening of existing buildings.

Lifelines Performance

1. The severe losses of lives in the collapse of the I-880 viaduct, which were fortuitously far less than the losses would have been under more normal circumstances, show the importance of successful performance of lifelines for life safety.

2. The disruptions of economic activities in the Bay area caused by failures of highway structures, and in the epicentral area caused by the landslides that closed State Highway 17, show the importance of successful performance of lifelines for the avoidance of property losses and consequent damages.

3. Water distribution system failures in the Bay Area show the vulnerability of U.S. cities in areas of seismic hazard to fires following earthquakes. Gas distribution system failures in the Bay and epicentral areas show a significant potential for ignition of fires following earthquakes. These failures were predominately

in areas of unstable soils.

Recommendations

These recommendations are based on the information gained in investigations to date of the Loma Prieta earthquake and on the state of the art of earthquake hazards reduction practices.

Performance of All Structures

1. **In all seismically hazardous areas of the United States, Federal agencies responsible for the seismic safety of Federal or federally assisted or regulated structures, and state and local governments responsible for regulations for buildings and lifelines should:**

   Plan and initiate systematic programs to assess the safety of existing buildings and lifelines and to correct those that are unduly dangerous. Particular attention should be given to structures sited on deep soil deposits which can be vulnerable to both nearby and distant earthquakes. Losses of lives and property and consequent damages in the Loma Prieta earthquake were due primarily to failures of structures not designed and constructed in accord with modern practices for seismic safety. To a large extent, these damages occurred to structures located on deep soil deposits. Those in the Bay Area were far from the area of earthquake faulting.

   Adopt and enforce modern seismic design and construction practices for new buildings and lifelines. Generally good performance of modern buildings in the epicentral area of the Loma Prieta earthquake shows the efficacy of modern design and construction practices. Tragic losses of 242,000 lives in Tangshan, China, in 1976 (China Academy of Building Research, 1986) and about 30,000 lives in Soviet Armenia in 1988 (Wyllie and Filson, 1989) show that earthquake losses are catastrophic in the absence of the adoption and enforcement of good seismic design and construction practices.

   Adopt and enforce modern practices for assessment of the stability of slopes and areas potentially susceptible to liquefaction to assure that undue existing hazards are identified and corrected and that new construction is not subject to ground failures in earthquakes. Significant property and consequent losses from ground failures in the Loma Prieta earthquake, and severe life losses in earlier earthquakes show the importance of prevention of ground failures affecting buildings and lifelines.

2. **Indepth studies should be made of amplifications of ground shaking by overburden soils and improved practices should be developed for site-specific design criteria for earthquake loadings.** Information from the Loma Prieta earthquake on main and aftershock

ground shaking intensities and on structural performance on deep soil deposits provides a strong data base for such studies.

3. **Indepth studies should be made of the effects of geologic structures and earthquake mechanisms on the directionality of the propagation of strong shaking from earthquake fault areas.** The marked irregularity of the intensity contours for the Loma Prieta earthquake show large potential for savings in costs of earthquake resistance and for reductions in earthquake damages when intensity distributions can be predicted more accurately.

4. **Methods should be developed for measurement of the properties of existing structures that will allow reliable pre-earthquake assessment of vulnerability and post-earthquake assessment of damages.** Experiences in the Loma Prieta earthquake reemphasize both the needs for these assessments and the inadequacies of currently available technologies.

Buildings Performance

1. **Successful and unsuccessful performances of modern buildings in the Loma Prieta earthquake should be studied indepth to formulated improvements for seismic design and construction practices. Recommendations from development of the NEHRP Provisions, FEMA 1988, emphasize the need to improve standards for the energy absorbing capacities of various structural systems.** The large variety of quantitative information on building performance in the Loma Prieta earthquake provides data for assessing and confirming analytical models for nonlinear structural performance in earthquakes that in turn can be used in development of improved design criteria.

2. **Successful and unsuccessful performances of buildings that had been retrofitted prior to the Loma Prieta earthquake should be studied indepth to confirm the validity of, or to improve, standards for the assessment and strengthening of existing buildings that presently are being developed in the NEHRP.** The large variety of data on performance of retrofit buildings available from the Loma Prieta earthquake provides a significant opportunity to evaluate and improve practices for the assessment and strengthening of existing buildings.

3. **Techniques should be developed for reduction of pounding damages for new and existing buildings.** Substantial pounding damages were observed in the Loma Prieta and in the Mexico City earthquake of 1985. Data are newly available for assessment of the adequacy of current criteria for new buildings design. Research can devise and verify techniques for mitigating potential pounding damages between existing buildings.

Lifelines Performance

1. **Analytical and laboratory studies of highway structures' supports should be conducted to improve design, assessment and retrofit practices.** Severe collapses and damages in the Loma Prieta earthquake and the fact that most of the U.S. highway system has not been designed for earthquake resistance show the need for these studies.

2. **Analytical, laboratory and field studies of the performance of gas and water pipelines should be conducted to develop improved design, assessment and retrofit practices.** Extensive failures and consequent fire hazards occurred in areas of unstable soils in the Loma Prieta earthquake. Similar potentials exist in most seismically hazardous areas of the U.S.

3. **Nationally applicable design and construction provisions for new lifelines, and assessment and strengthening provisions for existing lifelines should be developed in the NEHRP.** The Loma Prieta earthquake shows the importance of successful lifelines performance for the mitigation of life, property and consequent losses from earthquakes. In contrast to buildings, and except for highway structures, no nationally applicable design and construction practices are available for new and existing lifelines.

NIST RESEARCH AND TECHNOLOGY TRANSFER

P.L. 101-130, The Continuing Resolution Earthquake Appropriation Act of 1989, provided additional funding to the President for earthquake-related activities. The President allocated $2 million to NIST for investigations of structural performance in the Loma Prieta earthquake and for research in earthquake hazard reduction. In response, the following research activities are now underway at NIST. They are funded by NIST base funding, and funds from P.L. 101-130 either appropriated to NIST or transferred from USGS. Each activity is aimed at gaining knowledge needed for prompt improvements in seismic design and construction practices:

- Performance of highway viaduct structures in the Loma Prieta earthquake with recommendations for criteria for assessment and strengthening of existing highway viaducts, nationwide.

- Performance of retrofitted buildings in the Loma Prieta earthquake with recommendations for improvement of the recommended practices for assessment and strengthening of existing buildings that presently are being prepared by the Building Seismic Safety Council using FEMA funding.

- Research on performance of reinforced masonry walls. Recommendations for design of reinforced masonry walls for building and lifeline structures in areas of moderate seismic hazard will be made based on research by NIST and other laboratories.

- Research on performance of precast concrete frames. Recommendations for design of precast concrete frames for building and lifeline structures in areas of seismic hazard will be made based on research by NIST and other laboratories.

- Research on performance of bridge columns and piers. Recommendations for design of large columns and piers for railroad and highway bridges for reliable and economical seismic strength and energy absorption will be made based on laboratory and analytical research.

- Research on structural energy absorption. Research will seek consistent approaches for building and lifeline structures for: R values (ductility measures) and damping for design criteria, representation of duration of strong shaking in expression of earthquake intensity, criteria for loading history for testing of structures and components, and criteria for base isolation and energy absorption devices.

- Research on condition assessment technologies. Analytical, laboratory and field research will provide recommended practices for assessing the properties governing the residual strength and energy absorbing capacities of existing and possibly damaged buildings and lifelines.

- Research on site amplification criteria. Research will validate predictive models using observations in the Loma Prieta and other earthquakes and recommend practical site amplification criteria for design of new and assessment of existing buildings and lifelines.

NIST regularly coordinates its research planning with that of NSF and USGS through the NEHRP planning process, collaboration in the U.S.-Japan Panel on Wind and Seismic Effects and the Interagency Committee on Seismic Safety in Construction, and joint sponsorship of the National Academies' Committee on Earthquake Engineering Research and activities of the Earthquake Engineering Research Institute. NIST serves on the Oversight Committee of NSF's National Center for Earthquake Engineering Research at SUNY-Buffalo, participates in and conducts NSF-sponsored workshops to define research needs, and assists NSF in review of proposals. Special, intensive research coordination efforts were conducted by USGS, NSF and NIST following the Loma Prieta earthquake.

NIST's technology transfer efforts include both transferring knowledge gained by NIST to practice and to other researchers, and monitoring and collaborating in research activities worldwide to remain abreast of advances in knowledge elsewhere and to assist in transferring this knowledge to practice. In addition to participation noted above in the work of the Interagency Committee on Seismic Safety in Construction and the Building Seismic Safety Council, principal technology transfer activities include:

- U.S.-Japan Panel on Wind and Seismic Effects includes 16 U.S. Federal agencies and 9 Japanese agencies. NIST provides the U.S-side chairman. UJNR has:
  - held 21 annual technical meetings for prompt exchange of research findings
  - conducted 30 workshops and conferences, on topics such as repair and retrofit of structures, involving leading U.S. and Japanese researchers and practitioners.
  - conducted cooperative post earthquake investigations.
  - provided access for U.S. researchers to unique Japanese facilities.
  - organized cooperative research programs on steel, concrete and masonry structures.
- International Council on Building Research, Studies and Documentation (CIB). NIST has provided the President 1983-86 and serves on its Board and Programme Committee. CIB provides recommendations for international standards on structural resistance to earthquakes and international cooperation on earthquake hazard reduction.
- International Union of Laboratories for Testing and Research on Materials and Structures (RILEM). NIST provided the president 1982-85, and provides continuing leadership in development of its technical programs.
- NIST participates actively in over 100 national and international standards development activities. NIST provides the Chairman of the Management Group for Codes and Standards of the American Society of Civil Engineers, a major developer of standards for seismic safety.

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[3] Evaluating the Seismic Resistance of Existing Buildings, Applied Technology Council, ATC 14, 1987.

[4] Typical Costs for Seismic Rehabilitation of Existing Buildings, Federal Emergency Management Agency, FEMA 156, July 1988.

[5] Earthquake Engineering Research - 1982, Committee on Earthquake Engineering Research, National Research Council.

[6] Commentary and Recommendations of the Expert Review Committee, The National Earthquake Hazards Reduction Program, 1987.

Senator Gore. Thank you very much.

All the statements have been excellent.

Without objection, I am going to propose that we proceed as follows. I will defer my questions until last. I will recognize our ranking Republican member first, and then in order of arrival, Senator Gorton and Senator Lott.

Senator Danforth. Mr. Chairman, thank you very much.

Senator Gore's bill passed the Senate last October. It is awaiting action in the House. We hope that it will be enacted soon. And my question is, how are we doing in the absence of legislation?

It seems to me, really, there are two objectives. One is to try to promote building codes and construction codes so that buildings and other structures are more able to withstand earthquakes.

The second objective is to make sure that, in the event of a disaster, we know exactly what to do, and we are prepared to do it instantly. We must not have the situation in Armenia where planes were practically crashing into each other trying to get into the airport. And sometimes, of course, airports would not even be functioning if there were an earthquake.

So my question is, how are we doing? And I would like to direct it to Mr. Peterson.

Mr. Peterson. Thank you very much, Senator.

I think we have been progressing well, but there is a lot of work left to be done. In the area of mitigation, we have put out a large amount of information resources through our earthquake hazards reduction series. There are over 2.2 million copies out in the field at this time. These publications are directed to state governments, local governments, and schools and the general public.

The information transfer that is being generated from all of the work that the scientific community has been doing needs substantial additional work so it can be translated with the cooperation of agencies such as the Building Seismic Safety Council, which has been very good in doing that translation for us, and with the Interagency Committee on Seismic Safety in Construction.

But to get it into published form and down to state and local governments so it can be utilized for the purpose of state and local governments incorporation in their building codes requires a lot more work.

The coordination effort between the agencies is collegial, but needs to be more focused. Our budgetary process needs to be more collective and it will be one of the priorities of this agency to ensure that we have a collective, prioritized budget submitted to the President as your legislation requests. That is a priority.

The national workshop, which will be held in Washington, D.C. this year, on April 24 and April 25, is going to set some significant policy priorities. Additionally, the creation of an advisory commission is essential to help us set policy. So that is working and is forthcoming; I have made strong commitments to the Chairman that these things will happen.

In the area of response, we have learned a lot and we have come a long way in the last couple of years. The Catastrophic Disaster Response Group has been formed over the last couple of years. It includes 26 federal agencies and has 11 emergency support functions.

It has been exercised in Response '89 in California, with over 600 federal employees arriving on the scene in Sacramento to support California's emergency functions in response to a scenario along the Hayward Fault. It was extremely timely, because it was about 60 days prior to the Loma Prieta earthqauake.

We are having regular meetings of the Catastrophic Disaster Response Group at my level. We activated portions of the Federal plan during Loma Prieta, and, within two and a half hours, we were on the phone with a full committee of 26 agencies asking the state of California, what it needed.

That was the result of planning and exercising, and it shows our capability for response. We also used a major portion of those agencies very extensively in delivering goods in the Caribbean, everything from food to hospitals.

So our efforts are working, I think, fairly well.

One more thing, urban search and rescue is a new initiative. We do not now have a national capability. But have a new initiative for that on the plate, under the Administration's initiative, and so we are working towards that capability, sir.

Senator DANFORTH. I appreciate that, when I am told that there is virtually a 100 percent chance that there will be a major earthquake east of the Rockies between now and the year 2010, and when the New Madrid Fault has already been the site of one of the most severe earthquakes in the history of our continent, as far as we know.

I must say that I hope that we have the appropriate sense of urgency. I mean there are all these agencies that are out making reports and having meetings and whatnot. But it really has to be translated into real changes in buildings.

Mr. PETERSON. Yes, sir, I concur.

Senator DANFORTH. I mean real changes, not just more analysis and study groups, but real changes.

Mr. PETERSON. Yes, sir.

Senator DANFORTH. In fact, the earthquake in California was more severe, was it not, in seismic terms, than the earthquake in Armenia, but, less than 100 people died, as opposed to something like 25,000 in Amercia because of the codes and because of the response.

And my hope is that we would be very results-oriented in actually changing how buildings are put together, and making sure that when the event happens, and it will happen, we are ready to respond.

Mr. PETERSON. If I may take a moment, sir. California is unique, and is much more advanced than the rest of the United States. They responded well. Their building codes are in place. And where they had the built environment for earthquake-sensitive structures, they survived well. Where they did not, you saw a lot of buildings down.

I would be less than candid if I did not inform this committee that across the United States, in the 17 states we are working with and the eight states that want to set up an earthquake program, there is much to be done in building codes and mitigation for construction.

I would concur that it is the built environment that kills. We saw that there and we are moving forward with all expediency.

Senator **Danforth**. If the New Madrid earthquake of the early 19th century is repeated, it would be just a total disaster, would it not?

Mr. **Peterson**. It would be the single largest catastrophic event, short of nuclear war, this Nation could endure, I believe.

Senator **Danforth**. And the communities hit would include Memphis, St. Louis and other cities.

Mr. **Peterson**. Seven states would be impacted, sir.

Dr. **Peck**. On the back of my written testimony, Senator, there is a map showing the potential damage from a magnitude eight earthquake in the mid-continent. And again, because the shaking goes farther, the waves are not attenuated, there is severe shaking in Chicago, as far away as that.

And as Senator Gore pointed out, the construction scaffolding on the Capitol fell down.

Senator **Gore**. The last one rang church bells in Boston, too.

Dr. **Peck**. Yes.

As we compare the damage from the earthquake in Armenia and the damage from the Loma Prieta earthquake, also remember that the Loma Prieta earthquake was something like 75 or 80 miles from downtown San Francisco. And that was helpful, too.

Dr. **Hanson**. Senator, if I could make one point, addressed to your question. I think by establishing seismic building codes for new construction, we can, in fact, protect future generations of people.

But, as I stated in my written testimony and in my oral testimony, the real problem that we have are existing constructed facilities. And we can identify the classes of buildings that are hazardous, but within that classification, for example, unreinforced masonry construction, there are various degrees of hazard.

And we cannot afford to go in and fix every building, regardless of how good or bad the building is. So we need to be able to establish how good or how bad a particular building is, or establish techniques to determine how good or how bad it is.

We do not have that ability now.

Senator **Danforth**. Well, I would hope we would get on with it. I mean this really is something. What do we know? We know what happened in Armenia. We have seen it.

Secondly, we have been told that the likelihood is almost 100 percent. We have been warned. And really, there is no excuse for us, Congress and the relevant agencies, not doing everything that should be done to prevent it.

I mean, we think about whether we need to spend billions to protect the country against the possibility of nuclear war, which is a very remote possibility. And we are told that there is 100 percent certainty that there is going to be a major earthquake in the eastern part of this country.

It is going to be a total abrogation of responsibility if we do not do everything possible as quickly as possible. What happens if it happens next fall? You know, it is going to be worse than a week's delay in the All-Missouri World Series.

I am going to have to, unfortunately, go to another meeting right now. But I will be back. But I really wanted to impress on all of you the urgency. And I hope that the House acts quickly on the legislation. But even in the absence of legislation, time is of the essence.

Dr. WRIGHT. Sir, if I could just add a couple of words as to where are we right now, without legislation? We are coming into pretty good shape for new buildings, where the model building codes, we feel, by 1992, with current resources, will be up to date. And with important outreach efforts, such as Mr. Peterson described——

Senator DANFORTH. For new buildings?

Dr. WRIGHT. For new buildings.

Senator DANFORTH. Not the existing buildings?

Dr. WRIGHT. And they have to get into the legal building codes. Being in the model building code is not enough. The City of Seattle has to adopt, the City of Memphis has to adopt.

But with the current resources and the current efforts, these will be proceeding well in the early years of this decade.

With existing buildings, with planned and funded programs, we will have nationally recognized practices about the middle of the decade that are suitable, technically, for programs to assess existing buildings, determine those that are unduly hazardous, and recognized practices for strengthening them, economically.

That is about the middle of the decade. We are not yet started on the question of lifelines, water supply facilities, electric power, and recognizing San Francisco experience with earthquake damage and no water, you have another type of problem, a fire, that can spread the damage beyond that of direct earthquake damage.

So the lifelines are extremely important.

Senator DANFORTH. I would hope that all of you, but particularly FEMA, would let us know what else should be done. I mean, let us not have a situation where we say—if we had only done this, we would have been better off.

I would really hope that those of us who are in a position to do something, and we are not experts, be told what else should be done. And if there is too much diversity, if there is not enough organization, whatever the problem, money, whatever the problem is, that we would just be told, here is what we should be doing.

I am very sorry that I have to leave, I am late already, to introduce people at another committee. I will be back. But I very much appreciate your being here, and I hope that—I hate to say this to you, but I hope you are not sleeping very well.

Really, when you talk about catastrophes, this is it.

Senator GORE. Thank you, Senator Danforth.

Senator Gorton.

Senator GORTON. Dr. Peck, this question is primarily for you, although if any of the other members of the panel wish to comment on it, I would be happy to have their input.

Almost 20 years ago I was a part of a national association of attorneys general task force to study earthquake prediction. That occurrence is long enough ago so that I am not even sure why that organization was involved in that subject. But I found it to be a most interesting one.

Some of the reports which we received then, on progress toward an ability to make better predictions, seemed encouraging. I would really like your comment, and perhaps your extensive comments on a wide range of questions relating to earthquake prediction.

Senator Danforth has really pressed each of you on the importance of this subject, based on the proposition that there will be a mid-America earthquake some time between now and the year 2010, and that this probability is almost 100 percent.

What progress are you making? When are you going to be able to tell us that there will be an earthquake in a rather specific section of California, of South Carolina, of Washington or Missouri, within the next year, or within the next six months, and have at least some indication as to how severe it is going to be?

How much effort is being put into that? What kind of progress is being made? How high a priority should prediction be in what we are doing in connection with earthquakes?

Dr. PECK. Thank you, Senator.

Let me start by saying it is a tough problem. It is a tough problem, and I think we were a little more optimistic 20 years ago of some immediate progress on it, as a result of some of the findings by Soviet seismologists, than we are at the present time.

At that time there was some thought that the ratio of different types of seismic waves, a change of that ratio over time might give some indication of future earthquakes. And there have been some noteworthy predictions, including one by the Chinese. The earthquake occurred, and the city fell down, and the people had been evacuated.

We are putting substantial effort into it. It is part of five components of our program. The other components are important, too: Where are the faults? What is the nature of the ground? How is it going to shake?

That ties into application of building codes, so that isimportant, too.

Working closely with university scientists funded by the National Science Foundation and by scientists all over the world, including Chinese and Soviet and Japanese scientists, we are working on the problem.

We have made a lot of progress, I think, in forecasting the likelihood of earthquakes over periods of several years or decades. And the Loma Prieta earthquake occurred in a segment where we, the USGS, and the academic scientists had both predicted the high likelihood of an earthquake.

So we are beginning on well-studied faults, like the San Andreas, and other faults in California, developing the ability to make these forecasts. It is more difficult in regions like the mid-continent, where the faults—if indeed they are faults—are buried by the Mississippi alluvium.

And it is hard with very deep earthquakes, like those anticipated in the Northwest along subduction zones, where you do not have the fault outcropping.

As far as the actual prediction, in the short term, of the time and the magnitude and the location, we have a ways to go. I think what will happen is that in certain segments of the fault, as we study them intensively, we will begin to get a handle on making those predictions.

For example, by studying in detail the micro-earthquakes along a fault and viewing that in three dimensions, you can see regions of the fault, for example, in northern California, that have not broken yet, surrounded by regions that have broken in the last few years.

That pinpoints an area that might go next.

Then, there were some indications even from the Loma Prieta earthquake that there might have been geodetic changes several months before. There were those two precursor earthquakes, which we could identify as precursors after the major earthquake, but identifying at the time, we still have not figured out.

But there were some indications. There was a very low frequency magnetic signal that was detected by some scientists at Stanford who were studying other phenomenon. They were studying communication for the Navy. That may be an indication.

We have a very intensive experiment going at Parkfield, a small community on the San Andreas Fault, halfway between Los Angeles and San Francisco, that has had a magnitude six earthquake every 22 years or so.

Working carefully with the State Division of Mines and Geology and the State Office of Emergency Services, and NSF-funded university scientists, we are intensively studying and instrumenting that spot so that we can see whether there are premonitary phenomena that will indicate along that segment of the San Andreas.

So I think it is important that we continue these prediction efforts. Perhaps my colleague from the National Science Foundation would like to make some comments, too.

We are making progress, and I am optimistic that we will continue to make progress. But it is going to be like winning the war on cancer. We are going to win that war by getting a better understanding of different types of cancer. And it is a step-by-step effort.

Dr. HAYS. I was at a meeting last week, in fact, focusing on earthquake prediction, and bringing together people who study the mechanics of fracture—fault mechanics—and those who measure strain accumulation in the ground, and geodetic displacements, and specifically, the Parkfield experiment and other such cases were talked about.

I would like to make two points on that. One, as Dr. Peck said, it is very important where you are. There are earthquakes that occur near plate boundaries. We understand those reasonably well. Earthquakes of moderate size occur frequently so that you can do the sort of micro-seismicity experiment that Dr. Peck talked about.

But there are other earthquakes that occur far from plate boundaries, and even some earthquakes on plate boundaries, where the earthquake recurrence intervals are very long. You do not have the history of earthquakes that we have on the San Andreas, for example.

That is a big question.

Also, I think one of the things that came out of this meeting is that there is probably no single technique that is going to be able to predict earthquakes in all settings. And you are probably going to have to look at a lot of different things.

Sometimes you are going to have to look very closely at detailed seismicity. You may need to look at strain accumulations. You may need to look at regional seismicity and regional strain buildup.

There is probably not going to be a single easy answer to that question.

Dr. **Peck**. I may say, every few years, new technology is developed that helps in leading to an understanding. There is a marvelous new technology that has just now become operational, called Global Positioning System, GPS. There is a network of satellites being launched by the Defense Department that will allow us to locate, within a few millimeters or a centimeter, the location of a given spot.

This is going to allow us to understand the accumulation of strain over broad regions. Heretofore, by and large, we have focused right along the fault. Or, with the help of NASA, we have done very long VLBI measurements.

Now I think we will be able to develop a better understanding as to how a strain is accumulating, whether it is focusing in a specific area and hence, whether we should be looking at that specific area.

So as new technology is developed, I think we will make more progress.

Senator **Gorton**. Well, I certainly hope you keep at it. It is very frustrating to know for certain that something is going to happen somewhere in the next 20 years, but our problem is that we do not get people focused very well under those circumstances.

I just hope that you will keep us apprised of what you need from the point of view of research tools in order to help us deal with this problem. And certainly, when we get to the point where we have a pretty good idea that something is going to take place in the next year, whether it is in Puget Sound or near Memphis, or anywhere else, we will mightily focus our citizens' and constituents' attention to that proposition, and we will have a broad-based public support for preparation.

Dr. **Peck**. I think the senatorial forum that you and Senator Adams held in Seattle is the sort of thing, and that Senator Gore has been doing in the mid-continent region, the New Madrid region, is——

Senator **Gore**. He was saying New Ma-Drid for awhile.

Mr. **Peterson**. Senator Gorton, I was very pleased to hear my colleagues at the panel articulate the position in the way they did. Because I think we all have a responsibility to understand the good work that has been done. And there have been considerable expenditures along this line.

But there is honesty being presented here today. And that is, there is not going to be a quick fix for this particular aspect that we are dealing with, in identifying when that earthquake is going to come, specifically.

And so I think we need to keep pressing on in this area, and we need to look at it budgetarily, to ensure that we have consistency and the capability to continue to address those issues, and do not lose momentum. We must take advantage of all the technology that is coming on line.

But it also focuses on the need for mitigation. We know we are going to have these earthquakes. We are not going to be able to tell everybody exactly when, but they are getting very good at telling us where they think they are going to be.

Mitigation, building codes, the built environment, and the capability to respond to a catastrophic earthquake of this magnitude also has to have equal priority.

Senator **Gorton**. Thank you, Mr. Chairman, very much.

Senator **Gore**. Thank you.

I want to follow up on some of your questions, Senator Gorton.

For about 10 years, Dr. Peck, a USGS geochemist, named Dr. Michael Reimer, has been studying the concentration of helium in the soil at several locations along the San Andreas Fault.

The budget for his studies has been cut way back, just like all of the work to try and predict earthquakes. And he only has one of his 20 sites remaining. But I want to share with my colleague here what that site at Stone Canyon showed. He was monitoring the helium concentrations in the soil, and they followed this pattern, until one day prior to the Loma Prieta earthquake.

And then, all of a sudden, he got the highest readings ever recorded during the 10 years of the study. Then they fell back down, and immediately after that, the earthquake took place.

Now that appears to be a remarkable indication that something was happening along that fault line. Should we not be exploring the usefulness of this kind of prediction mechanism? Why would work that looks this promising be cut back by nine-tenths?

Dr. **Peck**. Well, it is unfortunate. Those are very encouraging results. And I am surprised I was not aware of them myself, Senator.

Because the funding has been level for the last 10 years or so——

Senator **Gore**. In real dollars it has been cut by more than a third.

Dr. **Peck**. In real dollars it has gone down 40 percent. We have had to do a number of things. The helium monitoring has been encouraging. That is why we started it in the first place.

There was a series of magnetic stations in the upper epicenter region that we were encouraging some years ago by some similar magnetic anomalies.

Senator **Gore**. This is low frequency electromagnetic radiation?

Dr. **Peck**. No, we were also trying higher frequency magnetic variations.

Senator **Gore**. Well, let me interject there. It is my understanding that several hours before the Loma Prieta earthquake, there was what some scientists regarded as a clear and unmistakable warning in the form of very strong signals of low frequency electromagnetic radiation.

Should monitoring equipment be set up for this kind of warning signal along the most hazardous fault lines? And should we also increase the attention being paid to helium concentrations in the soil which, at least in this case, appear also to be an accurate predictor of a quake?

Dr. **Peck**. Yes. Again, resources permitting, those are both areas that we need to explore.

Now we have talked to those Stanford researchers who detected the very low frequency magnetic response and encouraged them to prepare a proposal to put that instrumentation in Parkfield as part of our earthquake experiment so that we can indeed see if that was a phenomenon of the earthquake, or was it some solar variation or something like that?

Senator **Gore**. Dr. Hays.

Dr. **Hays**. That was a bit of what I was getting at when I said it does not look like any single technique will work in all cases. I do not know the specifics of the helium study that you mentioned, but I do know that in looking at strain records and creep records, there very frequently are small anomalies that rise above the general noise level.

The difficulty with these is that if one occurs immediately before an earthquake, it can be very encouraging to interpret that as a precursor. But then you look at the whole record and you find that there are other similar events that are not followed by earthquakes. And you find other earthquakes where this does not happen at all.

So it is a very difficult problem. The signals, for the most part, are small, and they do not rise far above the noise, and it is going to take a lot of time.

Senator **Gore**. Take a look at that one there that I just gave Dr. Peck.

Dr. **Hays**. The signal to noise is very high in this one.

Dr. **Peck**. That is very encouraging.

Senator **Gore**. Yes, it is. But here the guy has monitoring 20 sites, and his budget has been cut back to the point where he can monitor only one out of the 20. And it seems like he has been able to pull out the clearest signal I have seen yet that may be extremely promising.

Mr. **Peterson**. Senator Gore, I really appreciate that kind of information, as I know the committee does. And this is part of what we are trying to identify in these new national policy workshops that we are trying to bring together, and we are going to have here in Washington, D.C., to set priorities.

Obviously, this is an issue that should be looked at in a prioritization manner. It looks very fruitful. So we are going to try to be working that side of prioritization for fundings in these policy workshops and in the PCG meetings.

Senator **Gore**. All right.

In the next panel we are going to talk, Dr. Wright, about the federal building codes and why the Federal Government has been dragging its feet on the need to set an example here. I really appreciate the work that you have been doing over the years. And we are going to pursue some of the comments that you have made in questions to the next panel.

Regional seismic networks, they are being cut back and put at risk every year. And the basic information about specific fault lines collected in these regional networks is extremely valuable to use in conjunction with the kinds of studies we have just been talking about here, if we are ever going to get a way to predict earthquakes and give people warning when a major earthquake is on the way.

What about these regional nets? Have you been able to look into that, Mr. Peterson?

Mr. **Peterson**. I sure have, sir. And you are the one who sensitized us to that in a couple of meetings. And I appreciate that. We have information the regional and national networks. So the approach is twofold, and I am going to pass this to the USGS in a minute.

But I want to express to you that, as lead agency, we have the responsibility, I believe, to look into the funding and funding criteria that has been used, and is now being used for these regional networks. They seem to be of substantial worth.

That funding is in jeopardy. And we have other agencies that we work with as well, like the Nuclear Regulatory Commission, that has investments in this process, and as lead agency, we need to be, working with them as well, so that we have an understanding of where they are going and where we could encourage them to go.

This will be an issue in the national policy workshop. I make the commitment to you that we will wrestle that one out. And I support the efforts of USGS to resolve this issue. They have been working on it in support of the national seismic network, while we are still maintaining support for the more detailed regional networks.

And so we will deal with that, sir.

Dr. PECK. Some of the networks in the East are in particular jeopardy. The Nuclear Regulatory Commission has supported a number of networks in the East, including some in the midcontinent.

Senator GORE. TVA has, too.

Dr. PECK. And TVA. That, I think, may have been supported originally by the Nuclear Regulatory Commission and then passed over to TVA. In any case, it is in jeopardy, indeed, and the long-term support of some of the networks in the midcontinent.

Senator GORE. One of the best ones is in Memphis, is it not?

Dr. PECK. Yes, sir, and a very good one, right next to the New Madrid earthquake. It is in jeopardy. The Nuclear Regulatory Commission is supporting our effort to build a national network of seismographs. That will be a very important resource in understanding the phenomena. The regional networks are very important, too, because unless you have a good regional network you are not going to be able to really understand the fault itself and the strain release along that fault.

So I think both of them are complementary, and I am hoping that in the future resources will be of sufficiency that we can support those networks.

Dr. HAYS. I would like to add that the IRIS-developed seismic instrumentation, which was developed for research purposes, may also prove to be useful in staffing and equipping the local and regional networks

Senator GORE. All right. Very good.

Now on technology transfer, FEMA has been criticized in its role as the lead agency of NEHRP for not always being effective in transmitting research results that come out of, say, USGS or NSF to the end users; that is, the public and government officials in high risk areas.

I am sure you have heard these criticisms, also, Mr. Peterson. How do you respond to them?

Mr. PETERSON. I think, first, I want to take credit for what has been done well. Our earthquake hazard reduction series looks like just a piece of paper, but that is a tremendous amount of technological transfer. Over 2.2 million copies of this information have been disseminated in the United States nationally by request, and so I think that credit should be taken for that. It is a concerted effort.

I think we need to do more, and we need to do it better, and we need to do that through the counsel of the people who are sitting at this table. A substantial supporter in this area who has been very effective which we have been funding is the Building Seismic Safety Council. It has been taking that information and transferring it into documentation that can be understood at the State and local level, because that is where it has to be implemented.

With the enhancement before you in 1991, we intend to enhance the acquisition of that information in working with the BSSC and with the ICSSC, the Interagency Committee on Seismic Safety in Construction in support of the NIST's program to enhance and accelerate information transfer. The NEHRP agencies can do better. We need additional resources. We have some proposals on the plate, and I think there will be a direct result from that.

Dr. Peck. If I could interject a comment, Senator, there is an effort going on that we have not yet described today that is relevant to that. That is the International Decade for Natural Disaster Reduction, a program proposed by Dr. Frank Press, the head of the National Academy of Sciences, and taken up enthusiastically by the United Nations and the many nations assembled. That is both a national and an international aspect.

Part of the point of this is to look at the commonality of problems between different hazards but, more than anything else, to apply the knowledge we have to get the word out to people, to leaders at the local and State level, to utilize the information that we have. I think this is going to help the efforts of this group sitting here at the table to get that word out.

Mr. Peterson. I would just add one other thing, if I may, sir, and I mean this most respectfully. Most of the compliments we have been receiving from State and local governments have been on technology transfer. We have taken some pretty good hits as lead agency and on leadership, and we have made strong commitments to you to correct that. We do publications, workshop courses, and videotapes, and we are going to accelerate those.

Senator Gore. Okay, fair enough.

You are proposing in your fiscal year 1991 budget to increase staff for the earthquake program by 12; is that correct?

Mr. Peterson. Yes, sir, that is correct.

Senator Gore. Are any of these new staff positions intended for scientists or engineers?

Mr. Peterson. We currently have scientists and engineers on board; however, when we go from 23 to 35, it is imperative that we do acquire engineers to aid us in working with the expertise that is represented sitting at this table. So yes, we do plan on forcefully going forward to hire engineers and seismologists, et cetera.

There is a broad need across the base to be able to work on this, transmitting these six primary elements down to the local level, but I commit to you that we will emphasize that.

Senator GORE. So in figuring out who these new 12 people will be, scientists and engineers will be given some of those positions; right?

Mr. PETERSON. Yes, sir.

Senator GORE. I have some other questions on this subject of improving tech transfer for the record. I would like to pursue them here, but we are going to run short on time if we do not move forward.

Let me ask you about coordination, Mr. Peterson and Dr. Peck, and others if you wish to chip in here. To what extent are your budgets for earthquake hazards jointly planned?

Mr. PETERSON. They were not in the past.

Senator GORE. Okay. Well, that is enough.

Mr. PETERSON. I would like to go a little further. We have an Interagency Coordinating committee that has met seven times this year and deals with ongoing priorities and budget issues. I do not feel, however, that we have raised this to the level and degree that we should have in working amongst ourselves, establishing the priorities that will come out of the national workshop and our advisory committee, putting dollars directly against that, Senator, for what it is going to cost to meet those priorities and then taking that as a document to the President.

I am working very hard to do that. I have a commitment from this body that we will do that, and we intend to take that forcefully forward as a joint document.

Senator GORE. Does OMB review the earthquake program as a unit?

Mr. PETERSON. It is really under two shops, sir. We have a hearing examiner that looks at FEMA's budget over all, and then USGS has another hearing examiner.

Dr. PECK. And NSF has another one.

Senator GORE. So the answer is OMB does not review the earthquake program as a unit?

Mr. PETERSON. But I need to go forward, sir, if I may. I have talked to the administration about this issue and said that I have made strong commitments to meet the intent of the legislation, and that is that FEMA, as lead agency, will bring together this group for the policy coordinating committee, set the policies and develop a joint budget and then bring it to the President. Will OMB jointly bring its people together to review it? The answer is yes.

So I think we have that one pretty much nailed down in commitment.

Senator GORE. I hope so.

Dr. Peck.

Dr. PECK. Yes. The OMB, my perception is, has shown increasing awareness of the cross-cutting nature of some scientific problems and the willingness to look across budget categories. We have had a very good experience in global change in that, and they are now addressing other areas.

So I would say that we have a good likelihood of success of going together.

Senator GORE. You really like OMB, do you not, Dr. Peck?

Dr. PECK. Of course.

They were very responsive in the global change program over the last year.

Senator **Gore**. They are just terrific. I agree with you.

Mr. Peterson, it is my understanding there has never been a systematic seismic safety inspection of existing Federal buildings. Is that right?

Mr. **Peterson**. I believe that is correct, sir.

Senator **Gore**. What kind of information on Federal buildings is available?

Mr. **Peterson**. I am not trying to pass the buck, but I think there is more experience here in NIST that can deal with that. They are our agent in working with the interagency committee on seismic safety and construction.

Senator **Gore**. Dr. Wright.

Dr. **Wright**. Mr. Chairman, each Federal agency has been responsible for its own buildings, and as far as inventory inspection for seismic or other issues, that has been a matter of the priorities and programs for each agency.

What the interagency committee has done is to bring the agencies together collectively to develop the kinds of practices that they will use in their own programs.

Senator **Gore**. Well, most agencies do not give a hoot about it; right?

Dr. **Wright**. It is difficult, I think, for some agencies to sort——

Senator **Gore**. I mean except for OMB.

I am sure OMB has looked at its facilities carefully. Most of them, however, really have not, have they?

Dr. **Wright**. We have not tried to count them.

Senator **Gore**. Why not?

Dr. **Wright**. If we are requested, we will do so.

Senator **Gore**. Can we trigger that? We would love to get that information if you could provide it to us.

Dr. **Peck**. We have gone ahead, Senator, and strengthened two of our buildings in Menlo Park.

Senator **Gore**. Well, I would hope so.

Dr. **Peck**. That does not solve the whole problem. I mean, it is also not cheap. It takes resources.

Mr. **Peterson**. That is one of the prime answers. I think that some like the Veterans Administration and DOD should get credit for what they are doing. The Nuclear Regulatory Commission has established some criteria.

If we are going to bring this collectively together under an umbrella, I think the ICSSC with the NIST is the proper avenue, but there has to be resources there.

Senator **Gore**. Well, we want to give you all the authority to pull this together and get a coordinated focus. I mean, that is really what is needed.

Again, in this line of questioning I will submit others for the record.

As I said earlier, I would like to continue with you but we have another panel. They have been very patient, and we are going to have to move on.

I would like to close out this panel by thanking each of you for your time and your work and your willingness to come here. So thank you very much.

We will call our second panel now.

Mr. **Peterson**. Thank you for your support and interest, sir.

Senator **Gore**. All right. Our second panel is made up of Dr. James Beavers, Dr. Robert Whitman, Dr. John Cecilio, Mr. Donald Trilling and Mr. R. D. Ross.

Mr. Ross, we will start with you.

Mr. R. D. Ross is Director of the Missouri Emergency Management Agency and President of the National Emergency Management Association.

Dr. James Beavers is an earthquake engineer and a corporate fellow with Martin Marietta Energy Systems which now runs the Oak Ridge National Laboratory.

Dr. Robert Whitman is a professor in the Department of Civil Engineering at the Massachusetts Institute of Technology. He is also a geotechnical engineer and studies the stability of soils during earthquakes.

Mr. John Cecilio is the Chief Engineer for the Naval Facilities Engineering Command, and is responsible for seeing that naval port facilities, airports and other facilities are not vulnerable to earthquakes.

Mr. Donald R. Trilling is the Director of the Office of Transportation and Regulatory Affairs at DOT.

Dr. Wright and Dr. Hanson, are you still here? I would like you to remain available if you could. If we need to, we will slide some additional chairs at that end of the table if we need you to join this discussion.

Your prepared statements, as with the last panel, will be in the record in full. We invite you to proceed with a summary of your presentation at this time.

Mr. Ross, please proceed.

STATEMENT OF R. D. ROSS, DIRECTOR, MISSOURI EMERGENCY MANAGEMENT AGENCY, JEFFERSON CITY, MISSOURI, ON BEHALF OF THE NATIONAL EMERGENCY MANAGEMENT ASSOCIATION

Mr. Ross. Thank you, Mr. Chairman. Mr. Chairman and Members of the committee, I will speak today on behalf of the National Emergency Management Association, which represents the State Emergency Management Directors, as well as my own state and, of course, the Central United States Earthquake Consortium of which Missouri is a member.

Since so many states in this country are at moderate to high risk from the occurrence of a damaging earthquake, we construe the earthquake threat clearly as a national problem. That is true with all the State directors, and we strongly endorse the proposed two-year reauthorization of NEHRP.

This represents this NEHRP money insofar as the states, those out on the ground, represents the only continuous Federal funding resource available to the states and their local governments to build and implement their earthquake mitigation preparedness and response programs. For this reason, NEMA recognizes the diligent work of FEMA as designated lead agency for NEHRP. Also, we also laud the efforts of the other principal agencies of NEHRP as requested in your invitation to testify.

I would like to concentrate my remarks on the efforts of our State and local governments to meet the earthquake threat, particularly in view of the Loma Prieta earthquake.

As a Missourian and former chairman of CUSEC, I will draw examples from my own state's activities and our neighboring CUSEC member states. I would also like to offer several key recommendations on what more the Federal Government can do and how additional Federal agencies can play a greater role.

Many earthquake-prone states have been the beneficiary of slowly growing support from the executive and legislative branches of their respective State governments in recent years. For example, my governor in Missouri proposed and the legislature approved costsharing an earthquake planner for my staff in the last session of the legislature.

In his budget initiatives for seismic preparedness in the current session, Governor Ashcroft has recommended the following: another State earthquake planner to be located at either Cape Girardeau or St. Louis; a seismologist; and a data input operator for a new emergency information system with accompanying software.

In addition, Missouri has just recently hired its first resident area coordinator with emphasis on earthquake preparedness to be co-located at our Center for Earthquake Studies at Southeast Missouri State University in Cape Girardeau.

Since Missouri and the majority of other earthquake risk states have struggled in recent years with just a single planner per state, such new staff of course are welcome additions.

In Missouri, we are also looking to a new State emergency operation center which is being partially funded with Federal Civil Defense moneys through the survivable Crisis Management Program. The remainder of the project cost is being managed with State funds.

Certainly one of the major lessons internally that State Government in California learned with the Loma Prieta is the absolute necessity of a well-equipped, suitably sized EOC. Our conferees in California, led by my counterpart, Bill Medicovich, did a superb job certainly in responding to that earthquake; but they have complained bitterly about the lack of suitable EOC there. That is very important when the crises occur.

In Missouri, several seismic design and earthquake safety measures were introduced in the current legislative session, and I have a whole stack of them here. The first of the proposals is a Senate bill which incorporates the features of the original 1933 California Field Act requiring seismic design features for all new construction and major renovations of all Missouri elementary and secondary schools.

Another Senate bill would require schools to have a disaster response plan and to hold earthquake safety drills twice per year.

Another measure calls for the evaluation of all major buildings in the greater St. Louis area for earthquake safety capabilities, while another proposed law would require that new construction of commercial and public buildings be built to appropriate seismic design, as illustrated in national building codes.

What is happening in Missouri is certainly reflective of other states as well. Initiatives across the country briefly include:

One, a strong emergence of executive orders at the State and local level requiring nonstructural mitigation measures in government and municipal buildings;

Two, a tremendous increase in demand for earthquake mitigation and preparedness training courses and workshops;

Three, every state and certainly many cities within these states have increased their planning activities for the earthquake threat; and

Four, a major increase in public awareness of the earthquake threat through the media, community awareness projects and private sector involvement.

Following Loma Prieta, of course, there has been a marked increase in local television news specials dealing with the earthquake threat reaching audiences in key cities throughout the Nation. In our area, one major station in St. Louis while airing a three-part special on Missouri field team visits to San Francisco distributed its own earthquake safety information packet to the public which was done in partnership with the local grocery chain.

In Blytheville, Arkansas, schoolchildren there recently sponsored a Pennies for Safety Program to raise funds for nonstructural mitigation and earthquake survival materials for their schools. Their goal was to raise $8,650 in pennies, the amount that will cover their gymnasium floor. In fact, they raised over $11,000 with those pennies, and virtually everyone in Blytheville became more aware of earthquake safety and mitigation needs as a result of this exceptional project.

Currently, President Bush's executive order directing Federal departments and agencies to implement seismic design and construction features for new buildings has helped set the standard for states at risk to follow.

NEMA encourages more Federal participation, and you have been talking to that for the last couple of hours.

In terms of seismic safety, NEMA supports the use of Federal tax incentives, much like the government's solar energy credits in the 1960s, to be applied to reducing the earthquake threat. As a first priority, Federal tax incentives could be used to encourage nonstructural mitigation measures for a wide range of buildings, facilities and structures at risk to earthquake damage.

A special emphasis for nonstructural mitigation tax incentives should be placed on profitmaking high occupancy, high risk facilities such as schools, daycare centers, convalescent home/retirement centers and the like.

NEMA welcomes the participation of those Federal agencies which in some way oversee or guide the use of such high hazard, high occupancy facilities. Certainly the Departments of Health and Human Services and HUD and Education are key examples of such agencies which should be encouraged to play a new or expanded role in seismic mitigation and preparedness under NEHRP.

If the Federal Government elects to adopt an earthquake insurance underwriting program similar to national flood insurance, then the government will be in the position to deny such insurance to any building not seismically designed. The Federal Government could then also mandate time frames by which compliance must take place for all buildings.

The Federal Government through FEMA could also fund an education program and, in a sense, is for all structural engineers, utility engineers and architects to bring them up to current grade and seismic building proficiency. It might even be required that no structural engineer or architect could work on the design of a Federally-owned or leased building unless certified in earthquake design.

I might add parenthetically that only yesterday my state, the Missouri Professional Engineers Association have agreed to, in cooperation with my agency, to train their membership in pertinent professional courses and to provide inspectors for building assessments in earthquake-damaged areas.

In summary, NEMA supports an expanded Federal policy to stimulate cooperation among State and local governments, professional societies, universities and private firms in cohesive support of earthquake mitigation. Such interdisciplinary cooperation may be fostered best through increased public awareness programs.

The best locality to look to launch such efforts may be a university campus in cooperation with the State Emergency Management Agencies as Missouri has now done with its Center for Earthquake Studies that I mentioned earlier at Southeast Missouri State University in Cape Girardeau.

Similar university-based earthquake mitigation centers should be established in every state with an earthquake risk, jointly administered and funded through both emergency management and education funds.

Certainly earthquake preparedness is highly complex and involves full participation of all segments of the population led by government and must be sustained over a long period of time. NEHRP is the vital component of the Nation's earthquake preparedness program.

Mr. Chairman, I appreciate this opportunity to be with you, and that concludes my testimony.

Senator GORE. Thank you very much, Dr. Ross.

Dr. Beavers, I want to welcome you as a fellow Tennessean. You may go next.

STATEMENT OF DR. JAMES E. BEAVERS, CORPORATE FELLOW, MARTIN MARIETTA ENERGY SYSTEMS, OAK RIDGE, TENNESSEE

Dr. BEAVERS. Thank you, Mr. Chairman.

As an aside, as you know, I have spent about half my life in Tennessee, but for Mr. Danforth's benefit, I spent the first half of it in the state of Missouri, great state.

Senator GORE. You will be well received by this panel.

Dr. BEAVERS. Thank you. It is a pleasure for me to appear before you this morning in support of the reauthorization of the Earthquake Hazard Reduction Program.

Today I am proud to say that I am also speaking for the American Association of Engineering Societies, the American Society of

Civil Engineers, and the Earthquake Engineering Research Institute. These organizations have brief statements that I would like to have introduced into the record.

Senator GORE. Without objection, we will put that material in the record at the appropriate point.

Dr. BEAVERS. Thank you, sir.

In your letter of invitation I was asked to address a number of issues including what those federal agencies who are not a part of the program should do to improve preparedness, what must be done to ensure that Federal buildings and facilities are not vulnerable to earthquakes, and what agencies like the Departments of Energy, Defense and Transportation could and should do to address this problem.

Mr. Chairman, I have addressed all of the issues at length in my written testimony. What I would like to do now is cite my observations followed by recommendations for your consideration.

Observations: The probability of a damaging earthquake happening somewhere in the eastern United States within the next 25 years is better than 80 percent and it may approach 100 percent as was discussed earlier. It does not really matter whether it is 80 percent or 100 percent. The fact is, the risk is real, and we have to do something about it.

And, unlike California, the eastern United States is not prepared. Smaller earthquakes of Richter magnitude 5.5 can be disastrous causing deaths and damage in the billions as was just demonstrated in Newcastle, Australia. In direct losses the ripple effect could be two to three times larger than the direct losses.

What this means is that the total economic loss to the central United States from a catastrophic earthquake would not be $50 billion, but it could exceed $200 billion. The adoption of seismic codes for new construction by cities and municipalities east of the Rocky Mountains was almost nonexistent during the first decade of the program. Except in a few cases virtually nothing is being done to examine the vulnerability of our existing lifelines and building stock.

Understanding the performance of unreinforced masonry may be the most important mitigation issue east of the Rocky Mountains. Retrofit is a complex issue and more research is required. However, a technology base now exists to begin implementation.

After the first decade of our program the United States no longer finds itself the world's leader in the earthquake industry. Leadership now belongs to Japan. Our educational systems and corresponding laboratory facilities have declined during the last decade. The engineering and construction industries routinely do not invest sufficient resources into R&D. Technology transfer has been occurring at a snail's pace. The funding for NEHRP has been cut in half in real dollars over the past decade, and earthquake engineering research has continued to represent only a third of that funding. And lastly, the Federal Government has not been setting the example it should for the public sector. And except for the program agencies, the role of the other agencies for reducing the vulnerability is unclear.

Having made these observations, I would like to now make the following recommendations for your consideration. The order of these recommendations do not signify priorities in recommendations.

Over the next three years program funding should be increased to the $200 million as recommended by the expert review panel, except I believe that the NIST level should be increased to $6 million.

As a minimum I believe the NIST funding should be increase to $1.5 million for fiscal year 1991 and $2 million for 1992, and I might add, Mr. Chairman, that Dr. Wright did not pay me to make those statements.

The amount of funding for earthquake engineering and implementation activities should represent 50 percent of the funded program.

All Federal agencies that are members of the Inter-Agency Committee on Seismic Safety and Construction should report their activities in the program's annual report to Congress. All Federal agencies should be using state-of-the-art methodologies for design and construction of new facilities and evaluation and retrofit of existing facilities.

Increased or redirected funding levels must be provided in earthquake engineering to capture the lessons learned from Loma Prieta. Increased effort should be focused by the federal agencies, Congress and the administration on the vulnerability of the existing building stock especially on reinforced masonry.

Because of the complexity and potential cost to address the overall problem of earthquake hazard mitigation and as part of the international decade of hazard reduction, Congress should support and encourage the development of a program plan for the decade of the nineties with goals that can be accomplished and priorities established.

The Congress should develop incentives to encourage our engineering and construction industries to invest more into R&D. The Congress should continue to conduct hearings and support increased funding and public awareness while promoting the national movement toward earthquake preparedness.

The Congress should encourage a commitment from the Federal agencies, the professionals, and the public not unlike a cultural change to accept the fact that a hazard does exist and to mitigate the risk. And, lastly, the Congress should consider the establishment of a Federal earthquake oversight commission to oversee the program. Such a commission should report to Congress.

Mr. Chairman, understanding the earthquake threat and the implementation of preparedness throughout the United States is a complex and difficult issue. We have come a long way during the past decade but as has been visibly described to us by Loma Prieta and inferred to us by the recent quake in Newcastle, Australia, we have a long way to go.

With the appropriate resources, great strides can be made to mitigate the threat and the adoption and enforcement of seismic building code provisions for new construction is a first step, and the first step. We must effectively utilize our resources, we must continue our research, and we must begin to take action not only to provide life safety for our citizens and to reduce the economic losses, but to help maintain our global competitiveness for without being globally competitive, we may not be able to effectively provide the other two.

To do the job that must be done, the program must be expanded for the decade of the nineties. Without expansion, we will be shortsighted of the future and continue to hold our citizens hostage to a threat that could be mitigated. A lack of expansion will also result in this country's continued decline in the international marketplace.

As we move further along the road to peace in Eastern Europe and elsewhere, I hope Congress will seriously consider restoring this important program to the funding level required.

Mr. Chairman, that concludes my remarks, and I will be happy to answer questions later.

[The statement follows:]

Testimony of

Dr. James E. Beavers

Corporate Fellow

Martin Marietta Energy Systems, Inc.

Thank you, Mr. Chairman and Members of the Subcommittee.

It is a pleasure for me to appear before the Subcommittee on Science, Technology and Space in support of the reauthorization of the **National Earthquake Hazards Reduction Program**. Today, I am proud to say that I am not only speaking for myself but also for the American Association of Engineering Societies (AAES), which represents over half a million engineering professionals, one of their members, the American Society of Civil Engineers (ASCE), and also the Earthquake Engineering Research Institute (EERI), which represents the **"earthquake industry"** with 1700 earthquake experts in the various fields of engineering, geoscience, architecture, planning, public policy and social science. My testimony is based upon the approved policy statements of these organizations and I request that these statements be included in the record (Attachments).

My strong interest in the earthquake risk to this country and the need for adoption of earthquake hazard mitigation measures is a direct result of my current membership on the Committee on Earthquake Engineering (CEE) of the National Research Council of the National Academies of Sciences and Engineering; my past chairmanship of the Advisory Panel to the "Administration's" feasibility study on a National Earthquake Engineering Experimental Facility; my service as a member of the National Science Foundation's Advisory Panel for Critical Engineering Systems; my membership in EERI, currently serving on its Board of Directors and Editor of its professional journal, Earthquake Spectra; my concern about the rapid slippage of this country's world leadership role, not only in the manufacturing sector of which we are all painfully aware, but in the service sector of the engineering and scientific professions; and most of all my concern for the life safety and welfare of the citizens of this country.

Mr. Chairman, thirty-nine states in this country are at risk from damaging earthquake. We all recognize the seismic risk associated with living in California and other areas in the West. However, even with the great strides of the National Earthquake Hazards Reduction Program (NEHRP), the public is still painfully unaware and unprepared for a damaging earthquake in other areas of the United States, especially the central and eastern United States. During the winter of 1811/1812, the central United States was torn asunder by three "great" earthquakes estimated at having Richter magnitudes greater than 8.0, five greater than 7.0 and ten greater than 6.5. These earthquakes occurred in what is now known as the New Madrid seismic zone. This zone encompasses portions of Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri and Tennessee. Unfortunately, the public has no memory of that devastating winter because the area was virtually uninhabited at the time.

In addition to the New Madrid seismic region east of the Rocky Mountains, we have the Appalachian Region that was the host of an estimated magnitude 6.0 in 1897 in Giles County, Virginia -- an earthquake fault that is projected as being capable of a magnitude 7.0. Two hundred miles to the southwest of Giles County, an area in East Tennessee is known as a "hot spot" of seismic activity and is also within the Appalachian Region. Other areas in the East are also at risk. The Charleston, South Carolina area was host to a Richter magnitude 7.7 in 1886 resulting in over 60 deaths; the New England area experienced the Cape Ann earthquake of about magnitude 7.0 in 1755; and, of course, we have the St. Lawrence Seaway where an earthquake occurrence in Canada could have damaging effects on areas of the Northeast, even New York City.

Unfortunately, Mr. Chairman, we do not have as good a handle on the probability of a damaging earthquake occurrence in other areas of the central and eastern United States as we do in the New Madrid area. In the AAES publication of 1986 entitled *"Vulnerability of Energy Distribution Systems to an Earthquake in the Eastern United States -- An Overview,"* which I would also like to submit for the record, the statement was made that the probability of a damaging earthquake occurrence somewhere in the eastern United States within the next 25 years was nearly 100 percent -- an almost sure thing. In the context of this statement, a damaging earthquake was defined as one having a Richter magnitude of 6.0 or greater, the eastern U.S. was defined as east of the Rocky Mountains and the occurrence of a damaging earthquake included the likelihood of an earthquake in Canada causing damage in this country. Since that time, others have used this projection in their testimony, and it was reported in the **Wall Street Journal** on July 11, 1989. While the projection was based on the scientific work that had been done in New Madrid, the basis for the projection was more intuitive. Although such a risk projection may not be based solely on scientific computation, seismologists, geologists and earthquake engineers all agree that there is indeed significant risk. Simple probability calculations show the risk of occurrence of an earthquake of magnitude 6.0 or greater at around eighty percent when Canada is included. I have been told that the likelihood of the Loma Prieta earthquake was projected at being only thirty percent in the next thirty years -- yet it occurred on October 17, 1989.

I submit to you, Mr. Chairman, that we do not know the exact risk to the eastern U.S., but we do know that this risk must be reckoned with and that earthquake hazard mitigation measures must be adopted to save lives and reduce economic impact.

We must not forget that there are a few major differences between an earthquake in California and one in the central and eastern U.S. That is the affected area will be ten to twenty times greater in the East for the same magnitude earthquake occurrence in California. California has used seismic design and has had seismic building codes and building parapet retrofit ordinances for years. Additionally, we must not forget that eighty percent of the U.S. population lives east of the Rocky Mountains and sixty percent east of the Mississippi River. Depending upon the epicenter of the earthquake in the East, thousands or tens of thousands more people could be significantly affected than from a similar earthquake in California.

In the Federal Emergency Management Agency's (FEMA) six city study of the central United States, it is shown that nearly 5,000 deaths, 20,000 injuries and 500,000 homeless would occur in a magnitude 8.6 earthquake, and it has been estimated that the direct (shaking) damage would exceed $50 billion.

For a repeat of the Charleston, South Carolina earthquake of 1886, a similar study has shown that in a three county area, the number of deaths would exceed 2,000 and the direct damage would exceed $2.6 billion.

The damage associated with earthquakes has recently been etched in our minds by the vivid pictures of death and destruction from the Loma Prieta earthquake. The collapse of the Nimitz Freeway (I-880) come vividly to mind for many of us when the Loma Prieta earthquake is mentioned. This earthquake caused 67 deaths, 2,435 injuries and the direct damage has been estimated at $5.6 billion. I have heard projections that the total direct damage could exceed $10 billion.

Based on what we have just seen in San Francisco and other recent earthquakes around the world, I believe the damage estimations for New Madrid and Charleston may underestimate the effects of such earthquakes. In the study, *"Estimating Losses From Future Earthquakes"* by the National Research Council, it was found that: "...using the best of today's methods and the most experienced expert opinion...property loss estimates are often uncertain by a factor of 2 to 3, and estimates of casualties...can be uncertain by a factor of ten."

While the estimated property losses from a catastrophic earthquake in the central United States could be double the current estimate of $50 billion, this estimate does not include the indirect losses -- the ripple effect. In a Japanese paper that will be published in the EERI's professional journal, a methodology is presented for calculating expected indirect losses. This method is demonstrated by using the 1983 Nihonkai-chubu, Japan earthquake of Richter magnitude 7.7. In this earthquake, the direct losses were only 148.2 billion yen (1983 yen), while the indirect losses were 371.0 billion yen -- nearly three times higher than the direct losses.

Therefore, if this be the case, the total economic loss to the central U.S. from a catastrophic earthquake in New Madrid could exceed $200 billion. Mr. Chairman, this country can not afford $50 billion in losses, let alone $200 billion.

It is clear that we need to understand the potential economic impact of indirect losses. Preliminary information on an estimate of the indirect losses in the Loma Prieta earthquake is that such losses are in the range of $10 to $20 billion. However, Mr. Chairman, we were lucky in the Loma Prieta earthquake. If the duration of strong ground shaking of the Loma Prieta earthquake had lasted the twenty to thirty seconds typical of California earthquakes instead of ten to fifteen seconds, the twenty-five percent damaged unreinforced masonry buildings in San Francisco may have been fifty to seventy-five percent. Instead of the estimated direct damage being $5.6 billion, it could well have been $10 to $20 billion. Then, what about the indirect losses? If we apply the methodology mentioned previously, the indirect losses could be upward of $30 to $60 billion.

As Dr. Wright of the National Institute of Standards and Technology (NIST) has discussed in testimony, the San Francisco Bay area, where much of the damage occurred, was 60 to 70 miles from the epicenter, yet these losses occurred to a city that, in my opinion, was relatively prepared.

I submit to you the question, Mr. Chairman: What is going to happen if such an earthquake were to occur east of the Rocky Mountains in New Madrid, or Charleston, or just across the Canadian border? Approximately three million people are within a seventy-five mile radius of any point of the New Madrid fault. Memphis and Shelby County, Tennessee are only thirty miles from the fault zone; Paducah, Kentucky is less than sixty miles; Cairo, Illinois is on the fault; Cape Girardeau, Missouri is less than fifty miles from the fault, and what about those fifty or so small towns that litter the 200 mile length of the fault? Osccola and Blytheville, Arkansas; Tiptonville and Ridgely, Tennessee; Caruthersville and New Madrid, Missouri; and, Hickman and Columbus, Kentucky, to name a few.

Mr. Chairman, the eastern U.S. is **not** prepared.

Let's look at what might happen in the East from a small earthquake of Richter magnitude 5.5. First, an earthquake measuring 5.5 on the Richter scale is a highly probable event in the eastern United States in the next few years and could easily happen tomorrow. For example, we had the northern Kentucky earthquake of magnitude 5.2 on July 27, 1980, causing over one million dollars in damage. We had the northeastern Ohio earthquake of magnitude 5.0 on January 31, 1986, causing damage. To explain the damage possible from a Richter magnitude 5.5 earthquake, I will describe the events of such an earthquake. It was the first fatal earthquake in Australia's history and occurred on December 28, 1989. The earthquake struck Newcastle, Australia, an area similar to many medium-sized cities in the eastern U.S. because the seismic activity of Australia is much like the eastern U.S. Newcastle is in a geographic area known as Seismic Zone 0, modeled after the U.S. 1976 Uniform Building Code. Also designated in 1976 as being in a Seismic Zone 0 are the panhandle and southern half of Florida, the lower portions of Mississippi and Alabama and a large southeastern portion of Texas. Seismic Zone 0 requires no seismic resistance. The Newcastle earthquake caused fourteen deaths, 10,000 buildings suffered significant damage, 25,000 buildings suffered minor damage and the direct damage estimate is $1 billion.

Mr. Chairman, the occurrence of a magnitude 5.5 event could occur almost anywhere east of the Rocky Mountains. I do not believe there is much argument about the likelihood of such an event occurring somewhere in the East within the next 25 years. The only arguments would be where, when and what level of damage could we expect. Would the damage be less than that in Newcastle, Australia, or would it be greater? We really don't know. What we do know is that if the earthquake occurs in a lightly populated area, the damage will be less. If it occurs in a heavily populated area it could be much greater. There is one thing, however, about the

Newcastle earthquake that I have not told you. This earthquake lasted only five seconds. What would have been the direct damage to Newcastle if the earthquake had lasted ten seconds? Two billion, $10 billion or $20 billion? How many more lives would have been lost? What will the indirect cost be?

To prevent the events of the Loma Prieta and Newcastle earthquakes, cost effective earthquake hazard mitigation must be developed. We also must begin to prepare those people living and working in those areas east of the Rocky Mountains.

Earthquake engineering can and must be applied quickly and broadly. To begin with we must adopt and enforce cost effective seismic codes and standards for new construction. Progress has been made in this area, but today, only a few areas in the eastern U.S. have adopted such standards. In many areas of the U.S. the adoption process is stalled by vested interest groups because of perceived high increases in new construction costs. These groups believe that if such standards are adopted they will lose a competitive edge in attracting new business into their areas. Concerning the debate for adoption of a seismic code in Tennessee, I quote statements made by the opposition on January 22, 1990: "...Section 1206 of the 1988 edition of the Standard Building Code is unreasonable and unrealistic...this Section should not be adopted and promulgated by the state of Tennessee...Unrealistic and unwarranted building requirements will result in unrealistic and unwarranted building costs and higher rents, and will make our state less attractive to new business."

Mr. Chairman, I do not agree with such statements. "Trial designs" have shown that these costs are not insurmountable. We have an obligation to protect the health and welfare of the public. Today, Mr. Chairman, I am happy to report that on January 8, 1990, Shelby County adopted a seismic code, albeit not to today's standards, and on Tuesday of this week it is my understanding that the city of Memphis will have adopted the same provisions.

Mr. Chairman, the United States must be prepared. The "bottom line" is that the engineering profession has the basic technology of cost effective earthquake hazard mitigation waiting in the wings to be applied to new construction, but to be effective it must be adopted and enforced. I applaud the President for signing Executive Order 12699 on January 5, 1990, requiring all federal and federally funded new building construction to be designed for seismic loads. This will indeed set an example for the public sector to follow and will ensure that future federal buildings and facilities are not vulnerable to damaging earthquakes.

We must be aware, however, that when it comes to saving lives and reducing economic loss, such measures will not play a significant role in accomplishing these goals for the next 25 years. The real vulnerability in the United States lies in the existing building stock that was, and is continuing to be, constructed with no seismic provisions, especially unreinforced masonry. For the most part of this country, with the exception of California, this includes almost all buildings being built today.

Last November I attended a workshop at the University of Illinois sponsored by the National Science Foundation (NSF). The purpose of this workshop was to address the issue of **Structural Vulnerability Estimate, "Denver and East."** At that workshop, twenty-eight earthquake engineering experts concluded that the number one priority for earthquake research was understanding seismic performance of unreinforced masonry structures, and number two was nonductile reinforced concrete structures.

I submit to you, Mr. Chairman, that until we fully understand the performance of such structures, we will not fully understand the vulnerability and the risk to the nearly 200 million people of this country living east of the Rocky Mountains. We must keep in mind that unreinforced masonry construction is used almost exclusively throughout the 15,000 school districts that house the United States' 40 million grades K through 12 students. In the Memphis, Tennessee area alone, it is estimated that the number of deaths among school children will exceed 1,100 if a major earthquake occurred during a school day. We don't want to be reminded of those thousands of school children who died in the Armenian earthquake of Richter magnitude 6.9 on December 8, 1988, as a result of the collapse of 171 K through 12 school buildings.

Unfortunately, the existing building stock presents us with a much greater engineering, social and economic challenge. What are we going to do with our unreinforced buildings that are found almost everywhere in seismic areas of the East? What are we going to do about our nonductile reinforced concrete frame buildings? Are we going to abandon them? Are we going to upgrade them? Can we afford either choice?

Retrofitting is expensive. Based on the retrofit ordinance in the city of Los Angeles, retrofit for a typical unreinforced masonry building costs between $6 and $20 per square foot. A report on your bill S.1062 quotes $3 to $13 per square foot. For a small grocery market of 2,000 square feet, retrofit could easily cost $20,000.

This is a major economic burden on the owner. But we can learn from the California experience because such techniques might be applicable to the more vulnerable buildings in the most active seismic zones in the rest of the country. However, the simple fact is that the cost of retrofit is highly structure dependent, as well as dependent upon the seismic hazard level to which one is attempting to retrofit. I have experience in performing studies for critical structures where the retrofit cost can easily approach or exceed $100 per square foot.

Retrofitting works. In the Whittier Narrows earthquake of 1987, many unreinforced masonry buildings had been retrofitted and they did their job -- they provided life safety; however, many experienced serious economic damage.

The issue of retrofit is a complex one and only through education, research and study can we minimize the cost of retrofit while maximizing gains in earthquake preparedness. Unfortunately, I believe we have a long way to go before we come to grips with this issue.

If the scientific and engineering professions are to make advances toward reducing the loss of life of our citizens and damage to our industries and cities when destructive earthquakes occur, we must have a strong NEHRP for providing implementation of mitigation activities, for understanding through research and development and for identifying the more specific needs of research in the eastern United States that will lead us to more cost effective retrofit techniques.

Many new developments are occurring to assist us in these efforts. Today we have computer systems that have unlimited modeling capacity. However, Mr. Chairman, many buildings do not perform as we have modeled them. We have a lack of understanding of material strengths, material energy absorption capacity and material interactions. This is exactly why study of instrumented buildings in the Loma Prieta earthquake must be carried out and why my colleagues and I are pushing for the improvement of our experimental testing capability throughout this country. We must have the experimental capability to understand the performance of structures, of seismic isolation and energy absorption systems in order to refine our models.

The data collected by the United States Geological Survey (USGS) and the state of California from the Loma Prieta earthquake, due to a strong motion instrumentation program that has been in place for many years, will provide a wealth of information about the performance of structures in West Coast-type earthquakes. However, earthquakes east of the Rocky Mountains are known to excite buildings differently. A national strong motion program must be developed. In this case it is not a promising new development that needs to occur, but the application of existing technology.

The Loma Prieta earthquake has also provided us with a wealth of information on the performance of unreinforced masonry buildings--those that did well and those that did not. We have a unique opportunity to learn from this event, which I view as a new and promising development. Study of these structures should give us an understanding of which unreinforced buildings need retrofit and which do not. This type of information will greatly assist us in meeting the engineering, social and economic challenges of preparing existing building stock to withstand damaging earthquakes.

The earthquake industry has been developing new technologies to increase our safety, effectiveness and understanding of earthquakes. Developments in seismic isolation, energy absorption techniques and intelligent systems have shown great promise. The May 1990 issue of EERI's Earthquake SPECTRA will be devoted solely to the theory, application and socioeconomic aspects of seismic isolation. While the techniques of seismic isolation are not applicable to all building systems, there are such systems where seismic isolation is attractive and cost effective.

Energy absorption, both passive and active, has already been used on some buildings throughout the world. Although neither system has been tested by a large earthquake in the United States, the base-isolated San Bernardino County Law and Justice Center in Rancho Cucamonga recently experienced the largest motion ever recorded for such a system in the February 28, 1990, earthquake of Richter magnitude 5.5 near Upland, California. The foundation of the building experienced 0.15g while the building above the seismic isolation system only experienced 0.08g, a reduction of nearly one-half. Full understanding of the performance of this system awaits further analysis.

In the area of intelligent systems, we will have what may be called "smart" buildings. This is a promising new area in that the lifetime states of stress, including those caused by earthquakes, can be continually monitored in a building. It is foreseeable that a building would be so monitored that in the event of a destructive earthquake, the building could have its own warning system for the occupants to evacuate immediately, based on the state of stress in the building, and would provide data concerning decisions of reentry, continued occupancy, etc. Obviously, more research needs to be done in each of these areas to better understand their performance and ultimate applicability. Continued reductions in funding for the programs of the NEHRP can only extend the time needed to apply these new technologies.

Mr. Chairman, up to now, I have only mentioned building structure preparation and technologies. There is another major area of concern which must be considered: energy lifelines. This can be important for not only insurance issues as a result of environmental spills, liability, damage and repairs, but also life safety.

In the 1986 AAES study, mentioned earlier, it was shown that people hundreds of miles from the ground shaking effects of a major earthquake in the East could be directly affected due to the disruption of pipeline transmission systems. For example, if the natural gas pipeline route along the East Coast was disrupted by an earthquake in South Carolina, 260,000 residential consumers in South Carolina, 300,000 in North Carolina, 480,000 in Virginia, 850,000 in Maryland and the District of Columbia, and 3.9 million in New York could be without, or experience a shortage of natural gas.

While such an event may be considered unlikely, it is feasible to say that it could happen. Such an event could be devastating to people hundreds of miles from where the earthquake occurred, resulting in life safety issues and significant indirect economic losses. We must remember that over twenty-five percent of this country's total energy consumption is transported by pipeline and to some extent by water up the Mississippi River from the south and southwest northward through or near the New Madrid seismic zone. Therefore, we must be prepared to mitigate the damaging effects of a large earthquake. This can only be done through effective research, construction, planning and public awareness. Fortunately, the Building Seismic Safety Council, supported by FEMA, has begun to examine the issue of lifelines more closely. The Ecuadoran earthquakes of 1987, the largest being 7.3 on the Richter scale, resulted in the destruction of thirty miles of that country's main crude oil pipeline, forcing Ecuador to stop payment on its $8.2 billion foreign debt. Estimates of the economic impact are in the order of $1 to $2 billion, and estimates of the time required to restore the pipeline back to service range from four to six months.

When retrofitting lifelines, the California experience tells us that the use of the basic retrofit procedures for freeway overpasses could vary from $300,000 to $1 million. But how do we effectively retrofit a 40- inch diameter buried pipeline that is transporting, on the average, 700,000 barrels of crude oil per day through the New Madrid area? Such questions are not easy to answer. We know that the most likely point of failure is where these pipelines cross rivers and that there are fifty crude oil pipeline river crossings through the New Madrid area that have manual shutoff valves. How much oil might be released from a failed 40-inch pipeline pumping thirty thousand barrels per hour? Estimates on the breakage of a twenty-inch pipeline have shown that 650,000 gallons of crude oil could be spilled at a river crossing. The 1988 Ashland oil storage tank spill of 700,000 gallons cost $18 million in cleanup. If such crossings are by bridge, we can more easily retrofit. We do have the basic technology to retrofit; it really becomes a matter of education, cost effectiveness and feasibility. The uncertainty on the retrofit cost issue is exactly why it is important to conduct research on the expected performance of structures during earthquakes.

Seismic standards for lifelines, I believe, is as complex an issue as the adoption of building codes, and in many cases building codes can be used for lifeline standards. Lifelines include airports, oil and gas pipelines, electrical systems, dams, bridges, railroads, water supply systems, sewage systems, and telecommunications systems. Today, I know of no consistent use of seismic standards for lifelines east of the Rocky Mountains except for the construction of new bridges. Standards for other lifelines which can minimize the damage from a destructive earthquake have been developed but are not consistently used. The Alaskan pipeline that transports oil from the North Slope to the Port of Valdez is an example of where standards have been used. Again, the matter becomes an issue of priorities, first, in understanding the hazards and risks, secondly, in determining workable solutions, and, finally, in having the willingness and determination to implement them.

Mr. Chairman, as I have pointed out throughout my testimony, there is a great deal of work to be done. Major research and development efforts must be undertaken. But the continued decline of NEHRP funding in real dollars over the past thirteen years has resulted in earthquake engineering research programs being reduced in size rather than increased. Fewer future professional earthquake engineers are being educated in the university system, and at the same time, our experimental facility capability has deteriorated. We believe that there is a need to further increase the transfer of existing and newly developed knowledge to professionals at the state and local levels.

One of the most effective transfers of research knowledge into practice is through students who are employed by professionals and by direct interaction with these professionals in the research programs. This interactive cooperation of research and practice makes research more responsive to the needs of practitioners and more immediately useful to the profession. Increased support is now needed to provide practicing engineers and other design professionals with improved design and analysis techniques to enable them to better utilize existing knowledge.

This transfer is also important to our international competitiveness position. Mr. Chairman, in your remarks of May 18, 1989, when you introduced S.1062, to amend the Earthquake Hazards Reduction Act of 1977, you stated: "The United States is a world leader in earthquake research and in earthquake preparedness..." As you may recall, in my 1987 testimony, I expressed the opinion that the "earthquake industry" was another industry where the United States has indeed lost its leadership role. I cited evidence of this in the events after the 1985 Mexico City and 1986 San Salvador earthquakes. It has been three years, almost to the month, since that testimony, and now, I believe, during those three years we have continued to slip.

Mr. Chairman, the United States is no longer the world leader. The Japanese have passed us by, leaving us in the dust. Other countries are not far behind. I strongly contend that while the "earthquake industry" is only a small part of this country's international structure, it is representative of what is happening with other small parts. This loss will have a major impact on the ability of our engineering and construction firms to compete in the global environment. As an example, the Japanese equivalent to the NEHRP received $2 billion in 1989, thirty times the NEHRP amount. The ratio between private industry spending on earthquake engineering in Japan and that spent by private industry in the United States is even greater. Considering the NEHRP and its Japanese equivalent, the United States contributes less than two-thousands of one percent of its GNP or $0.27 per capita while Japan contributes one percent of its GNP or $16 per capita. If you put the relationship in terms of land area, the United States is spending $18 per square mile while Japan is spending $14,000 per square mile. Such funding disparity over the past ten years has indeed led the Japanese to become today's world leaders in the earthquake industry.

From the international competitiveness perspective, the lack of research in earthquake engineering, especially in the experimental area, is beginning to have a profound effect on our ability to compete for construction projects overseas. It has been stated by some that the balance of world economic power has shifted to the Pacific Rim and that the United States can greatly benefit from these newly emerging economies. At the same time, it is also posed that we should stop looking to Europe because the European Economic Community (EEC) will have a smaller impact on the United States' economic future. Ironically, the Pacific Rim is the most active area of destructive earthquake occurrences throughout the world. The countries of China, Japan, Taiwan and New Zealand each have earthquake activity that greatly surpasses that of California. During the decade of 1975 to 1985, over half a million people were killed due to earthquakes around the Pacific Rim. The total economic impact, which was in the billions, has never been determined. If the United States is going to be a major economic power and maintain economic relations with those countries of the Pacific Rim, understanding the global impact of a devastating earthquake should be an important factor to success.

What I have said here today, Mr. Chairman, only reinforces my concerns about the issues that face us in earthquake mitigation for the decade of the 90s. To meet these concerns we must continue the NEHRP with an increased level of funding and also provide a better focus for those activities undertaken by other agencies. Based upon my limited knowledge, the non-NEHRP agency activities vary considerably between agencies. For example, it is not clear to me what the Department of Housing and Urban Development (HUD) has been doing the past few years. However, following the San Fernando earthquake of 1971, HUD was one of the first to develop methodologies for seismic evaluation of existing buildings, and HUD is a participant on the Interagency Committee on Seismic Safety in Construction (ICSSC).

The Department of Energy (DOE) has had an active program for the development of seismic design and evaluation guidelines during the past decade and currently has an active program in evaluation and upgrade of existing critical facilities. DOE is also an active participant in the International Decade for Hazard Reduction and ICSSC. During the week of October 1, 1989, DOE held its second national conference on mitigation of natural phenomena hazards.

The Department of Defense (DOD) also has active programs. For example, under the DOD it is my understanding that the Navy has an excellent program of evaluating the vulnerability of their facilities, and some of their work has been published in professional journals. Additionally, the Corps of Engineers also has an active program, especially in the area of dam safety.

Under the auspices of NEHRP, many of the non-NEHRP agencies do participate in the annual report to the United States Congress. In the 1989 report, those agencies participating were the Bureau of Reclamation, DOE, Department of Transportation (DOT), National Oceanic and Atmospheric Administration (NOAA), Nuclear Regulatory Commission (NRC) and the Tennessee Valley Authority (TVA). In the case of the nuclear power related agencies, NRC and TVA, the level of earthquake-funded activities is on a decline because of the decline in the nuclear power program.

About once a year CEE invites the agencies to present briefings on their earthquake programs. In the short time frame allotted for these briefings, it is very difficult to obtain any appreciation of their activities.

It is not clear to me how some of the non-NEHRP agencies are staffed and organized to carry out their activities. Some agencies may have a staff person who has been representing that agency at seismic meetings for years, yet in some cases that person is not in the division that would ultimately have responsibility for evaluating or retrofitting existing buildings. Also, while some agencies may be active at the national level, based on my knowledge, such activity does not get down to the local level where the work must be carried out.

To improve the nation's earthquake preparedness and to ensure that federal buildings and facilities are not vulnerable to earthquakes, I believe the agencies need to work more closely together. They currently have the avenue to do this through the ICSSC.

In the 1989 NEHRP report to Congress the ICSSC member agencies that did not contribute were: Department of Agriculture, General Services Administration, U.S. Postal Services, Department of State, Department of Health & Human Services, and HUD. The Veterans' Administration has had an extensive hospital upgrade program in the past, but was not a part of the 1989 report.

It is possible that all of the ICSSC agency members should be included in the NEHRP report to Congress, for without such reporting it is difficult to grasp what the agencies are doing. I also believe the agencies should be using a state-of-the-art code approach for new construction and should be using leading edge methodologies for evaluation and upgrade of existing buildings because the federal government must set the precedent for the public sector to follow.

Recently the Federal Construction Council (FCC) Consulting Committee on Civil and Structural Engineering was asked to assemble information on the nature and status of current federal efforts to eliminate seismic hazards in existing federal facilities. To gather the desired information the Committee developed a questionnaire and sent it to the federal agencies represented on the Committee. While the report is now in draft it is my understanding that of the some twenty-eight agencies represented, only seven responded to the questionnaire.

It appears to me that the non-NEHRP agencies need a better focus and commitment to the problem. Executive Order 12699 may help provide this focus and commitment, but, again, it does not address existing building stock. I believe that it is very important that the agencies understand the seismic vulnerability to their facilities and the impact of damage to such facilities, if any, on the public. I know this has been done by the VA for their hospitals and is being done very vigorously by some agencies such as the NRC and DOE and, to some extent, by the DOD. However, in the case of noncritical facilities such as office buildings, it is not clear that much activity is occurring. Mr. Chairman, this country must understand its vulnerability before we can do something about it. Because of the costs involved we must prioritize the effort. Recently, ICSSC published guidelines for identifying hazardous existing federal buildings. It is now time to begin to implement these guidelines.

Mr. Chairman, we have learned from the Loma Prieta earthquake that the central and eastern United States must be better prepared. San Francisco was prepared. They have had a seismic building code since 1927; they have the best water distribution and fire protection systems in the United States; they had just completed an earthquake emergency drill three weeks before the earthquake and they have had a building parapet retrofit ordinance in place since the 1970s. Even with this level of preparedness, San Francisco still experienced significant damage.

The NEHRP must be continued and, hopefully, expanded for the decade of the 90s. Without expansion we will be shortsighted of the future and continue to hold our citizens hostage to a threat which could be mitigated. A lack of expansion will also result in this country's continued decline in the international marketplace.

AAES, ASCE, EERI, and I feel very strongly about the recommendations and concerns that follow. We fully support the reauthorization of NEHRP but at an increased funding level so that the assigned task of its implementation by FEMA, USGS, NSF and NIST can be carried out effectively. We applaud the Congress for taking positive action by granting an additional $20 million following the Loma Prieta earthquake, but before we can really make great strides in earthquake preparedness in the eastern United States, a greater increase in sustained funding of NEHRP must occur.

As you well know, the Senate Report on S.1062 showed that, in 1989 dollars, NEHRP funding has been reduced by over $30 million since its inception in 1977--a fifty percent reduction. This is exactly why the eastern United States remains woefully unprepared. Although S.1062 and H.R. 3533 may help, I submit to you that without a stronger commitment from Congress and the Administration, we will not see a great increase in the rate of progress during the next few years. The NEHRP Expert Review Panel recommended the NEHRP funding should be at a level of about $200 million: USGS $80M; NSF/EAR $18M; NSF/ENG $66M; NIST $4M; and FEMA $30M. This distribution provides approximately $100M for earth science activities and $100M for earthquake engineering and implementation activities. Although the rationale for this distribution was weighed carefully by the Expert Review Panel and EERI supports this split, I believe that the NIST funding level should be $6M in order to carry out fully their role of technical support for the improvement of standards. In fact, I believe that the 1991 budget request by NIST should have been $2M rather than the $0.53M. Because the NIST earthquake program has been operating at the meager level of $0.5M for the last several years, they have lost highly qualified staff and stature in a field where they too were considered leaders.

To improve the leadership issues, to be assured the agencies are focusing their activities properly, to assure they are doing their fair share, and to fully understand what the agencies are doing, I believe that a Federal Earthquake Oversight Commission must be established. As much as I am against adding to the bureaucracy, I feel that an Oversight Commission is required and this Commission should give guidance to the lead agency, FEMA, review and monitor each agency's activities and report to Congress at least annually. The Expert Review Panel made this recommendation over a year ago, and as a member of the CEE, I know that this will be one of its recommendations when it reports its review of earthquake engineering research to the Congress this year. I know that a Commission will not be popular with the agencies but I have seen enough over the years in such matters that I see no other alternative. The "bottom line." Mr. Chairman, is if an activity is to be carried out, someone has to be in charge and that someone must be responsible.

Understanding the earthquake threat and the implementation of preparedness measures throughout the United States are complex and difficult issues. However, with the appropriate resources, great strides can be made to mitigate the threat. Obviously, the adoption and enforcement of cost effective seismic building code provisions for new construction is a first step. Even where great strides have been made in earthquake preparedness, as in San Francisco, we have still seen what devastation can occur. As Dr. Ian Buckle of the National Center for Earthquake Engineering Research has said about the Loma Prieta Earthquake: "In the final analysis, we were really lucky; however, the earthquake showed us that we don't know as much as we would like to think we know." Throughout the United States we must continue to be vigilant and we must never take the earthquake threat lightly.

Mr. Chairman, we must effectively utilize our resources, we must continue our research and we must begin to take action, not only to provide life safety for our citizens and to reduce the economic losses of a damaging earthquake, but to help maintain our global competitiveness, for without being globally competitive, we may not be able to effectively provide the other two. As we move further into the peace initiatives that are occurring around the world, I would hope that Congress will seriously consider restoring this important program to the funding level required. AAES, ASCE, EERI and I stand ready to serve. Thank you.

Senator GORE. Thank you, Dr. Beavers.

Dr. Whitman, we will go to you next, and we appreciate

STATEMENT OF ROBERT V. WHITMAN, PROFESSOR, DEPARTMENT OF CIVIL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. WHITMAN. Mr. Chairman, Senator Danforth.

Mr. Chairman, first of all, let me say I appreciated your remarks at my institution last Monday, on the subject of energy and environment. They were very much to the point.

Mentioning Massachusetts, I want to add it to the areas with an earthquake problem as has been emphasized by just a released report, funded partly by FEMA. This report suggests that a repetition of the earthquake we had 200 years ago in 1755 would cause 300-odd deaths, 12,000 injuries, and at least $5 to $6 billion worth of damage.

The only reason that the predicted number of fatalities is so low is because we have, since 1975, had in effect a building code requirement for earthquake design.

First, a few comments concerning last October's Loma Prieta earthquake from the standpoint of soft ground.

Once again, there was evidence of the dangers posed by construction upon landfills created before the problem of liquefaction was understood. The earthquake underscores a national problem in this regard. Looking positively, all of the more recent, engineered fills throughout the Bay area showed no traces of this damaging phenomena, showing that something can be done.

There was also unequivocal evidence from strong motion recordings, almost a first for the United States, that soft soils do amplify ground motion. On the negative side, this amplification certain contributed to the collapse of a portion of the Nimitz Freeway and to the damage in the Marina District. On the other hand, many new buildings and structures sited over soft ground were undamaged, and some of the credit must go to requirements in building codes that this amplification effect be considered.

Inevitably there is the question: Could more have been done and can more be done now to prevent or reduce such tragedy-causing damage? Often this question is prefaced by: "In view of all the money that has been spent for research."

In the case of natural ground and landfills that may be susceptible to liquefaction, doing something of course requires that private owners and/or governmental bodies be willing to spend money for remedial action. The same is true regarding the strengthening of buildings or structures with inadequate seismic resistance. You gentlemen know better than I the reasons why such people may tend to oppose, avoid or postpone such steps. In other words, the answers to the question primarily involve economics and politics.

However, I do wish to address the two closely interrelated matters of research needs and dissemination of research. For there to be such dissemination, there must be three points to the effort. First, there must be people and organizations—the decision makers—who are interested in and prepared to have their results from research disseminated to them. Secondly, there must be engineers or scientists versed in the application as well as the results of research and willing and able to interact effectively with the decision makers. And, thirdly, there must be a body of knowledge and facts sufficient to allow the resolution of conflicts and differences of perspectives.

As for the first group, there unfortunately are many people and organizations that are not motivated to learn from research. For most owners and engineers there is little, if any, business incentive to improve the practice of designing against earthquakes. Outside of California, even those building officials who recognize and care about the earthquake problem often find little or no support from the administrative or legislative bodies to which they are responsible. Hence, the problem is not entirely on the side of the researchers. Education is part of the answer, but this process is inherently very gradual. Teaching classes and writing reports is a notoriously inefficient means of disseminating research.

Effective dissemination requires active participation by researchers in the decision-making process. In California, and to a lesser but still significant degree elsewhere, there have been engineers and academicians who have worked hard to bridge this gap between research and practice. The positive experiences related to soft ground during the Loma Prieta earthquake can be credited largely to the leadership of the late Professor H. Bolton Seed of the University of California at Berkeley. Among the academic researchers across the country, there are many more who desire to play similar roles. Unfortunately the attitudes and practices at many major research universities discourage such participation. Driven by the inadequate funding made available for education, these universities have increasingly come to rely on research monies to support their operations. Faculty, especially younger faculty, experience great pressures to write proposals and to publish papers, and unfortunately participating in actual engineering is often viewed as a diversion from this primary focus. NEHRP alone cannot solve these problems, but the realities of it must be recognized.

Concerning the third corner of the triangle—knowledge and facts—one major obstacle in my view to the adoption of research results is the continued slow pace of engineering research, insufficient for providing reasonably clear answers to many difficult problems.

For example, liquefaction is still not fully understood and, hence, experts differ in opinions concerning the need for corrective actions. Information concerning the effects of ground conditions upon earthquake shaking is adequate only for very oversimplified code requirements. Methods for site improvement and for strengthening existing buildings have still not received adequate testing. As long as these situations exist, those decision makers who wish to oppose, avoid or postpone difficult decisions find ammunition for not acting.

What can be done now and what can Congress do? There are several recommendations that I consider crucial.

First, insist upon and provide funding for an adequate national program for recording strong ground motions during actual earthquakes and for the processing, dissemination and research upon the resulting records. Such data and analyses are essential for making sound recommendations concerning the zoning of the country and microzoning of regions and cities, and also are a basis for developing design requirements and methodologies.

This information is especially needed to permit the selling of such recommendations to decision makers. This program must be controlled jointly by engineers as well as by seismologists, and funds for research based upon the recordings must be given to universities as well as at government laboratories. The effort that now exists does not meet these criteria and is so inadequately funded as to be technologically out of date.

Second, provide adequate funding for greatly expanded and improved facilities for large scale testing of structures and their components plus—and this is very important—adequate funds to support the operation and use of these facilities. I speak here, for example, of shaking tables, reaction walls for pseudodynamic testing, earthquake simulators for use on geotechnical centrifuges and sites and facilities for testing structures and soil systems in the field. Such steps are essential if the country is to move expeditiously to develop and test cost-effective means for identifying and strengthening potentially hazardous structures and sites. The facilities now available in this country are to some extent out of date and certainly too few, a shadow of those available and in use in Japan.

In this task alone an additional $25 million per year should and can effectively be spent. It can be argued that monies for such efforts should come primarily from the private sector. Perhaps they should, but the private sector seems to have found little reason or incentive to act meaningfully in this way, again in contrast to the situation in Japan and some other countries. The Federal Government must take stronger leadership in this area.

Finally, a "do not." Do not cut back on funding to individual principal investigators at universities and other such organizations. To do so will only compound the problem. Insecurity concerning research funding has already caused many young excellent faculty who are the keys to new developments in the future and to education in earthquake engineering to move into other fields or to leave academia entirely. A firmer base for research support will make it more possible for these faculty to resist administrative pressures to concentrate solely on science.

Before closing I do want to recognize the good efforts that have been made by FEMA, NSF, NIST and the USGS, especially during the last five years. FEMA has used well the available monies to fund the development and issuance of recommended design requirements for new and existing buildings and lifelines. NSF has repeatedly shown leadership in directing research toward the more pressing problems and has tried its best to lure participation from the private sector via the sharing of costs in research and large scale testing. The Center for Building Technology at NIST, with constant uncertainty over its very existence, has made very useful contributions to the development of design requirements, especially those for Federal buildings and facilities. The USGS with a small part of its funds earmarked for engineering and applications has been quite effective in helping cities and regions outside of California to begin facing up to effective mitigative action.

However, as earthquake engineering is still the front line of hazard reduction and as the pace of action has been too slow, more funds are needed for research to support decision making for action. Thank you.

[The statement follows:]

Testimony by

Robert V. Whitman
Massachusetts Institute of Technology

Senate Commerce Commitiee, Subcommittee on Science, Technology and Space

29 March 1990

I am Robert V. Whitman, Professor of Civil Engineering at the Massachusetts Institute of Technology, Cambridge, Massachusetts. I appreciate greatly your invitation to discuss the re-authorization of the National Earthquake Hazards Reduction Program.

By way of introduction, following graduate education in structural engineering, I have for 38 years been involved in geotechnical engineering with specialization in dynamic problems. Since the middle 1960s my efforts have focused primarily upon earthquake engineering - mostly, but by no means entirely, in the geotechnical area. At one time or another I have been involved with seismic risk analysis and preparation of loss estimates, probabilistic modeling of the hazard of ground-motion shaking and the drawing of zoning maps, evaluating fragility relations for buildings, liquefaction, effects of local soil conditions upon ground motions, soil-structure interaction, design of earth dams and earth retaining structures, and building code development. I have been a part engineering projects in Japan, Venezuela, Chile and Italy as well as in the United States. I have served on advisory boards for the National Science Foundation, the US Geological Survey, the Federal Emergency Management Agency, the Office of Science and Technology Policy, the National Academy of Engineering and I am past president of the Earthquake Engineering Research Institute - which, as you know, is a national professional society. I am currently chairman for the Scientific Advisory Committee for the National Center for Earthquake Engineering Research at Buffalo. In Massachusetts, I was a member of the committee that developed and helped put in place in 1975 the earthquake design requirements in the statewide building code.

I say all this to emphasize that I came at the earthquake hazards mitigation challenge from a broad viewpoint - as an educator, a researcher, an engineer and as a concerned citizen. In this connection, I would mention a recently-released loss estimate for metropolitan Boston - which indicates that a repeat today of the 1755 Cape Ann earthquake might cause 360 fatalities, nearly 12,000 injuries and in excess of $5 billion in damage.

In my testimony today, I want to discuss three matters: geotechnical experiences during the Loma Prieta Earthquake, the dissemination of research results into practice and high priority needs for increased research in earthquake engineering.

The Loma Prieta Earthquake

Late in the evening of last October 17th, a close colleague in the San Francisco area called me - as he often has immediately after other major earthquakes - to tell me what he knew about the effects of this event. He told me this was a "structural engineering" earthquake, with little to interest for geotechnical engineers. He has usually been correct in his assessments, but this time he was dead wrong. The earthquake proved clearly the major influence of soil conditions in the Bay Area upon earthquake-caused damage - confirming the message long preached by the late Professor H. Bolton Seed of the University of California, and by others.

There were widespread instances of failures to important facilities as a result of the phenomenon known as liquefaction, in which shaking causes sandy soil to assume some of the characteristics of a fluid. The most striking of these occurrences were at the Oakland Airport and the Port of Oakland, where there was slumping of dikes, settlement of pavements and appearance of sand boils. Portions of these facilities have been out of service for some time following the earthquake. There was also clear evidence that softer soils amplify ground motions, thereby increasing the danger of damage to buildings and structures founded on these soils. The sharpest example occurred at Treasure Island, where the measured peak acceleration on the soil of that island was nearly twice that recorded on rock on adjacent Yerba Buena Island.This feature was mainly responsible for the unusually large accelerations recorded in Oakland, and contributed to the collapse of the elevated Nimitz Freeway. The considerable damage in the Marina district of San Francisco was the result of an unhappy coincidence of both amplification and liquefaction. These are only the more prominent of the examples that can be cited.

The questions arises: Why, if the problems had already been recognized, hadn't something been done to mitigate the hazards? In fact, much had been done.

For at least two decades, new fills placed for land development in the Bay Area have been required to be stabilized prior to construction of buildings, houses and other facilities. From what I understand, there was no evidence of liquefaction in any of these engineered fills. In addition, there are isolated cases where existing land had been improved prior to construction of new buildings. There was a clear example of this on Treasure Island, with excellent performance in a treated area and liquefaction at adjacent areas.

As for soil conditions and ground shaking, modern codes require greater resistance to earthquake shaking in buildings constructed over soft ground than those built where foundations rest on rock or stiff soil. This is done via the use of soil factors - factors by which the forces required in design are multiplied. In San Francisco as in the East Bay, there were many examples of modern buildings built over soft ground that fared very well during the earthquake. It cannot be proved that the soil factors were responsible for this good performance, but certainly they contributed. Professor Seed had for many years argued that the soil factors then in codes might not be large enough, but those who influence the requirements in codes - developers, some engineers and some building officials - resisted change, often arguing that there was insufficient evidence to justify larger soil factors that would require more costly construction. With the window of opportunity provided by the 1985 Mexican Earthquake and utilizing funds provided by the National Science Foundation, Professor Seed produced new studies that convinced the Structural Engineers Association of California, and thence the International Conference of Building Officials, to adopt a doubled soil factor for very soft soils - and the wisdom of this step was proven by the Loma Prieta Earthquake.

What more can be done? Where new construction is concerned, there exist a variety of satisfactory methods for checking sites as regards to liquefaction susceptibility. In California, and to a lesser degree elsewhere, geotechnical engineers are well aware of these procedures, and are prepared to put them to use. However, often - even usually - there are no laws requiring that special measures be taken at sites identified as being a problem. The Massachusetts Building Code is unique in requiring consideration of possible liquefaction as a prerequisite for obtaining a building permit. In the absence of such laws or requirements, owners frequently are unwilling to recognize the risk. Part of the problem is that is that there still are uncertainties concerning the liquefaction phenomenon and there can be disagreements among experts concerning the liquefaction susceptibility of a particular site. It would be far easier to convince authorities to require suitable actions, and for engineers to recommend them, if these remaining uncertainties and disagreements could be removed by further research.

There also exist methods for improving sites where liquefaction is found to be a potential problem. Such site treatments can be quite expensive, especially where there is already existing construction. While, as mentioned previously, there are instances in which such actions to stabilize soils have proven their worth, the bank of data from field tests and earthquake experiences is still very scant - so that it is difficult for engineers to chose the best method of treatment for a specific site and to give convincing evidence that the treatment will be worth the cost.

The same points can be made concerning the effects of local site conditions upon ground motions. The problem is clearly recognized in general terms, and there are theoretical methods for analyzing the situation at specific sites. Once again, however, uncertainties and disagreements remain - and provide the arguments for those who oppose imposition of restrictions or requirements upon the use of land. Here there is a particular need for more instrumentation to record ground motions during future earthquakes and for detailed analysis of both existing records and those to be obtained in the future.

I will return to these research needs in subsequent parts of my testimony.

Dissemination of Research Results

First, it must be recognized that the situation concerning dissemination of research into the practice of designing and constructing buildings and other facilities is quite different from that in other areas of technology. The practice of design is controlled by codes, regulations and standards of practice, which change only slowly with time. Owners expect their engineers to follow accepted practice, and the fee arrangements through which engineers are paid discourage experimentation with new and more sophisticated methods of analysis. Lacking very thorough testing of new concepts and systems of construction, the liability laws of the country inhibit innovation. Because buildings and other structures tend to be unique - one of a kind items - it is almost always very difficult to justify expensive testing and development in connection with a particular project. This situation also limits the opportunities for commercialization of the fruits of research - although in other countries the construction industry has been much more awake to the possibilities of competitive advantages than this industry in the United States.

Second, in view of these obstacles I believe there has been an excellent track record of dissemination of research in earthquake engineering into practice. Certainly some small portion of university-based research is and has been very basic in nature, leading slowly to results whose benefits cannot be predicted. Some such research of course leads to dead ends - the price of expecting researchers to explore many possible leads. However, the bulk of research in earthquake engineering has been of an applied nature and has readily found its way to engineers who are motivated to put it to use. I have already given examples of what went well regarding the geotechnical aspects of the Loma Prieta Earthquake. In that earthquake, and in all recent major earthquakes, there has also been clear evidence that modern buildings, properly designed using the fruits of research, have performed very well.

This useful dissemination into use has been the result of efforts by those engineers who have made it a practice to stay in touch with research and by those researchers who are active in engineering practice. Students who are involved in research while in the universities and who then enter practice have been especially important in moving the results of that research into usage. Several professional organizations have been particularly effective in bringing together research and practice: the Earthquake Engineering Research Institute, through the meetings, seminars and workshops that it organizes; the Applied Technology Council - chartered by the Structural Engineers Association of California just for the purpose of expediting technology transfer; and others. The National Science Foundation has always devoted significant funds to support efforts such as these. I feel that the Federal Emergency Management Agency has done well with its limited resources to stimulate and assist the development and publication of design guidelines and manuals. I also commend the US Geological Survey for its programs to assist communities and regions in identification and characterization of earthquake hazards.

As always, more yet could be done to improve dissemination. There is a need for more papers that synthesize the results of research and for additional monographs and design guidelines. A major obstacle is the lack of people qualified and motivated to undertake such efforts. The promotion and tenure policies at US universities do not reward such efforts - primarily because the national neglect of the educational establishment forces universities to give first priority to obtaining still more research funding. Engineers in practice are there primarily to engineer - not to write. Such problems can, to some extent, be helped by devoting more money to the dissemination effort.

In the final analysis, however, most engineers are not finding out about the results of research because they have little incentive to do so. Until more parts of the country require attention to the earthquake problem, until innovation in design is better rewarded, and until the construction industry begins to play as significant a role in advancing research as is the case in other countries, the pace of dissemination in the Unites States will remain snail-like.

NEHRP and Earthquake Engineering

Earthquake engineering must move forward on many fronts. Undoubtedly the greatest need is for recognition and action upon the earthquake hazard in more parts of the country - a challenge that is primarily political but one in which engineers must play a central role. However, there are two technical problem areas especially in need of increased attention:

- Development of cost-effective methods for increasing the earthquake resistance of existing hazardous structures, in all parts of the country.

- Reducing greatly the uncertainties concerning the phenomenon of liquefaction, and methods for reducing this hazard, and concerning the effects of local soil and topographic conditions upon earthquake ground motions.

In both cases, the most important requirements for progress are expanded and improved experimental facilities and funding for the effective use of these facilities.

I have already mentioned some of the obstacles to further progress concerning the geotechnical problems. Advancements here are primarily dependent upon testing in the field.

There is need to modernize and expand the number of strong motion instruments deployed on the ground (and in structures) in the several more seismic areas of the country. There is need for more arrays to reveal the effects of local soil and topographic conditions upon ground motions, and to give data concerning the build-up and dissipation of the excess pore pressures that are the cause of liquefaction. However, such an expanded investment will go for nought unless there are also expanded funds for researchers to study and analyze the recordings and to draw the important lessons from them. A major deficiency in the current program is the paucity of funds available to university-based researchers - in both engineering and seismology - for this purpose.

There is also need for field tests of methods for improving sites where liquefaction is an identified problem. The lack of such testing is a major impediment to the development and use of new and more cost-effective methods for site treatment.

On the structural side, there must be enough testing facilities - with shaking tables and strong-backs - so that the development and proving of new concepts and better methods for strengthening existing buildings can proceed at a more rapid pace. This means that existing facilities must be upgraded and that additional facilities must be established. Once again, it means that funds sufficient for the effective utilization of such facilities must be available.

Large earthquakes are, of course, the most important laboratory. It is vital that they be used effectively to document and understand what went wrong and what went right. Congress responded quickly to appropriate more funds for such studies following the Loma Prieta Earthquake, although I was saddened that the funds earmarked for engineering studies were so small.

In the table that follows, I have attempted to allocate into several categories the funds now spent yearly by the federal government for earthquake engineering research and dissemination, and have suggested levels of funding that I consider necessary for an adequate rate of progress in earthquake hazard reduction. The numbers are my own impression of what is being done and what should and can be done, and I am sure that there will be disagreement with them. It is indeed very difficult to pin down numbers of this type, and doubtless dangerous to make the attempt.

	At Present	Appropriate
Infrastructure for research	$ 2M	$ 15M
Individual investigator research	$ 7M	$ 15M
Focused team research	$ 9M	$ 40M
Dissemination	$ 4M	$ 10M

The first category includes new strong motion instrumentation, field test sites and laboratory facilities. The second category includes the basic research that will provide the new ideas and methods of the future, and as well as individually-focused applied research efforts. The third category encompasses the very important field and laboratory tests and the efforts of teams of researchers to interpret the results into a form meaningful for application; this money would be spent at a smaller number of facilities.

A comment about field and laboratory testing of structures and of methods for soil improvement. In other fields of engineering, and in other countries, work of this type might be undertaken primarily by industry. However, in the United States this happens seldom, and hence it is vital that the Federal government be involved to a significant degree - partly to make sure the necessary level of research and development moves forth, and partly to stimulate the construction industry to action. One possible approach is through matching funds, as in the example of the partial support from NSF for testing of reinforced masonry structures - supplementing construction industry monies. I hope there can be more of such co-operative efforts once the funds available for research are increased.

I do have several additional thoughts concerning the role of universities. I can understand the concern - of practicing engineers, building officials and elected representatives - that there may be too many engineering researchers that pay more attention to their science than to the applications of it. The first point is that basic research is vital - without it, earthquake engineering will stagnate. The second point concerns the state of the educational enterprise in this country - especially that in engineering education. Perhaps unintentionally, the country has created a system whereby universities depend for their existence upon research grants. Naturally, administrators have come to judge faculty on the basis of their accomplishments in research - not their contributions to engineering. The blame for this must be shared by both the universities and by Federal and state governments, and all should work together to evolve a solution. This will not be easy and will require time as well as imagination. In the meantime, it is essential that NEHRP continue to do its share in supporting research at universities.

Finally, a brief comment concerning the safety of Federal buildings and facilities. I am pleased that the Administration has finally issued an executive decree requiring attention to the earthquake problem in buildings under their control or ownership. All branches of the Federal government must now face the problem of what to do about existing buildings with poor seismic resistance. They will find that past research has provided considerable guidance, but that one must work to apply this knowledge - and that there is need for further research and development so as to have available even better and more cost effective methods for strengthening such structures.

I thank you for this opportunity to present my testimony.

Senator GORE. Thank you, Mr. Whitman. Mr. Cecilio.

STATEMENT OF JOHN CECILIO, CHIEF ENGINEER, NAVAL FACILITIES ENGINEERING COMMAND, DEPARTMENT OF THE NAVY

Mr. CECILIO. Thank you, Mr. Chairman. It is a pleasure for me to be here to testify as a Department of Defense witness. Detailed technical data which we did not duplicate has been provided in separate testimony by Dr. Richard Wright of the National Institute of Building Technology. Much of this data was developed by the Interagency Committee on Seismic Safety in Construction, and the DOD is very active in this Committee.

I would like to give you a summary of where we stand in DOD, particularly in the Navy, on criteria and surveys for buildings. Joint Army-Navy-Air Force criteria for structures has been maintained since mid-1960. Our latest update on criteria is nearly complete and scheduled for publication by the spring of 1991.

The current criteria for lifeline utilities, including water, sewage, gas and electricity and telephone needs additional work to develop a survival system that is economical.

Concerning new buildings: All new DOD facilities are planned, engineered and designed and constructed in accordance with current criteria. Buildings of this type performed exceptionally well in the 1989 Loma Prieta California earthquake. Current DOD criteria meets required implementation of the recent executive order, 12899 of 5 January 1990 entitled "Seismic Safety of Federal and Federally-Assisted or Regulated New Building Construction."

The existing buildings in DOD, particularly the Navy—the Navy initiated an earthquake hazards reduction survey program 15 years ago for all buildings in seismic zones 3 and 4. The seismic safety investigations identify site hazards and utility deficiencies as well as hazardous structures. The program is about 85 percent complete at this time, more than 14,000 structures have been screened, 1,400 analyzed, and 750 found to be vulnerable to serious potential damage.

Upgrading projects are initiated and prioritized by the operating commands in conjunction with all other projects. Additionally, a policy has been issued requiring that modernization and repair projects for structures in zones 3 and 4 include seismic mitigation, if necessary. This applies to projects where costs exceed 10 percent of the replacement cost or $150,000, whichever is greater.

Survival of the DOD infrastructure. DOD infrastructure will function through reasonably projected earthquakes, since all infrastructure built since mid-1970 has been in accordance with the current earthquake criteria at the time of construction. The primary area of concern is lifeline utilities, where retrofit is much more complicated and expensive. DOD will continue to develop methods to correct the lifeline utility situation, including mobile resources that can be quickly activated.

Sources of seismic technical data that DOD uses. We work with the Federal, DOD, State, professional and foreign groups who are working on seismic technology. The state-of-the-art will continue to improve.

DOD future plans. We will continue to support and work closely with the National Institute of Standards in Technology, Interagency Committee on Seismic Safety and Construction, to coordinate the development and publication of national seismic criteria for retrofitting of existing facilities, including buildings, lifeline utilities and roads; new construction planning, engineering, design and construction; maintenance and operation of seismic elements of facilities.

We will continue the survey of all existing DOD facilities in seismic zones 3 and 4 to identify all potentially hazardous facilities, including lifelines and roads. The hazardous facilities will be upgraded.

Mr. Chairman, this concludes my prepared remarks. Thank you for the opportunity to testify.

Senator GORE. Thank you very much, Mr. Cecilio. I am impressed with what the Navy has done.

Mr. Trilling, you finish out our witness list today. Thank you for your patience.

STATEMENT OF DONALD R. TRILLING, DIRECTOR, OFFICE OF TRANSPORTATION REGULATORY AFFAIRS, OFFICE OF THE SECRETARY, DEPARTMENT OF TRANSPORTATION; ACCOMPANIED BY RICHARD BEAM, OFFICE OF PIPELINE SAFETY; AND JIM COOPER, FEDERAL HIGHWAY ADMINISTRATION

Mr. TRILLING. Thank you, Mr. Chairman, Senator Danforth. With me today is Richard Beam of our Office of Pipeline Safety and Jim Cooper of the Federal Highway Administration.

As Department representatives to the Interagency Committee on Seismic Safety in Construction (ICSSC), I am very appreciative of the opportunity to appear before you today. I am also pleased to note that we have just delivered to Congress our report on our assessment of the adequacy of current Federal and State earthquake design standards for highways, mass transit and aviation.

The Loma Prieta earthquake was barely several hours old before Secretary Skinner was on his way to the site. In the hours following the tragedy, as President Bush's lead official on coordinating the Federal response, he gave this disaster immediate top priority.

In the weeks following, he continued to give it a great deal of his attention, working with the Congress to assure that emergency relief funding would be forthcoming. In all, the Secretary has made three trips to the affected area, meeting each time with the Mayors of San Francisco, Oakland and other impacted cities, and coordinating with FEMA and the other agencies to help cut through red tape.

Earthquakes can strike without warning and with devastating force, claiming thousands of lives and costing billions. The time to minimize the loss of life and to reduce the interruption of vital transportation functions from earthquakes is before they occur.

The Federal Highway Administration has been working on this problem for over 20 years. Following the 1971 San Fernando earthquake, with CALTRANS, FHWA began exhaustive studies into the seismic performance of bridges and began developing specifications to make them more earthquake resistant.

CALTRANS, the National Science Foundation, the Bureau of Standards and the United States Geological Survey (USGS) were all parties to this research. FHWA spent about $3 million on this work. By 1979, FHWA had completed its guidelines and succeeded in getting these adopted by AASHTO as guide specifications in 1983. Thus, all states were provided improved criteria for increasing the seismic safety of highway bridges.

You asked us to address the vulnerability of pipelines. The 450,000 miles of transmission pipes in the United States are constructed and financed entirely by the private sector. In 1970, safety regulations were promulgated covering design and construction of new pipelines, including a requirement that they take into account external loads such as earthquakes.

A majority of today's pipelines, however, were constructed prior to 1970. During last October's earthquake, there was no failure of natural gas or petroleum transmission lines in the affected area. Natural gas distribution systems, however, being made of cast iron, are more subject to earthquake damage because of their brittle nature.

The Marina district experienced considerable damage due to cast iron pipes. In contrast, the Palo Alto municipal system, constructed of steel and plastic pipeline, suffered little damage. Cast iron pipeline is slowly being replaced in the distribution system through the substitution of steel or plastic.

Transportation buildings and structures may be made more secure against earthquake damage through two methods: 1) designing in seismic strengthening before construction, or 2) retrofitting. Designing in is usually far more efficient, but it can still add 3 to 5 percent to construction costs for a typical building. Retrofit tends to be very expensive, but in some applications can be cost-effective.

In the bay area, many lives were saved because CALTRANS had prioritized its vulnerable bridges and already expended more than $60 million on implementing the retrofit program. In construction, since not all geographic areas are equally seismically active, constant trade-offs must be made within each region, measuring the level of hazard at a given locality against the cost of risk reduction for facilities there.

In January, Secretary Skinner instituted four initiatives for the Department. The first was a seismic design awareness program. In this effort, we will be pulling together the existing information developed under the auspices of the NEHRP and putting it into usable form for our constituents.

We will be adding technical sessions on earthquake design in various conferences, including those sponsored by the Transportation Research Board (TRB), the American Public Transit Association (APTA) and the American Society of Civil Engineers. These provide the opportunity to alert managers and planners in the development of projects, highlighting safety measures that are available and appropriate to deal with the consequences of major earthquakes.

The second initiative was development of uniform standards for DOT programs. We are developing a uniform Department philosophy for seismic design for both our safety regulatory functions and for guidance to our grantees. Again, these will draw on the quality material prepared by the ICSSC and will in many cases exceed the current building codes, particularly in certain Eastern cities.

The third initiative was the development of a retrofit policy. Although most retrofit projects are very expensive, there are some cases where low-cost improvements by DOT constituents would be warranted. For example, a $20,000 expenditure can add considerable protection against collapse of a bridge span and thus save lives. We need to develop a policy on when and where retrofit is appropriate.

Finally, we are assessing our own facilities and functions, taking an inventory to assess their seismic vulnerability. This will include the number of occupants, the criticality of their functions, their geographic region, and their construction type, with an eye towards identifying those with the highest priority for seismic strengthening.

I would like to conclude on the note that when a major earthquake occurs, transportation systems and services have an importance that goes far beyond their every-day function. If the transportation facilities are able to withstand destructive tremors and continue operations, this will have benefits far beyond the importance of any single building, airport or bridge.

The ability of utilities, communications, hospitals, supply depots and key government facilities to respond in the wake of a major earthquake's devastation, to sustain and to assist rescue and relief efforts and to assist subsequent economic recovery, will depend directly on the resilience we have built into the transportation system.

That concludes my prepared testimony, Mr. Chairman. I will be pleased to answer your questions.

[The statement follows:]

STATEMENT OF
DONALD TRILLING
DIRECTOR, OFFICE OF TRANSPORTATION REGULATORY AFFAIRS
U.S. DEPARTMENT OF TRANSPORTATION (DOT)
BEFORE THE SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE, COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION, UNITED STATES CONGRESS
MARCH 29, 1990

Good morning Mr. Chairman and members of the Committee. With me today is Richard Beam, Deputy Director of the Office of Pipeline Safety, and James Cooper, Deputy Chief of Structures Research in the Federal Highway Administration (FHWA). Under my responsibilities as Department representative to the Interagency Committee on Seismic Safety in Construction (ICSSC), and as Chairman of the DOT Seismic Safety Committee, I am very appreciative of the opportunity to appear before you today. I am pleased to note that we have delivered our report to Congress on our assessment of the adequacy of current Federal and State Earthquake Design Standards, as required in House Report 101-301.

The Loma Prieta earthquake was barely several hours old before Secretary Skinner was on his way to the site. In the hours following the tragedy, as President Bush's lead official on coordinating the federal response, he gave this disaster immediate top priority, assuring that everything possible was being done during the emergency. In the weeks following, he continued to give it a great deal of his attention, working with the Congress to assure that emergency relief funding would be forthcoming, (which eventually reached the amount of $1 billion), to help the area rebuild their highways and bridges. In all, the Secretary has made three visits to the affected area, meeting each time with the mayors of San Francisco, Oakland, and the other impacted cities, and coordinating with The Federal Emergency Management Agency (FEMA) and the other agencies to help cut through red-tape.

We in the Department of Transportation are fully aware of the sudden loss potential of major earthquakes. As we have seen in the last few years, earthquakes can strike without warning and with devastating force, claiming thousands of lives and costing billions of dollars. The time to minimize the loss of life and to reduce interruption of vital transportation functions from earthquakes is before they occur. For this reason, the Department continues to expend considerable effort in seeking measures which will reduce the long-range vulnerability of facilities and structures for which DOT provides financial aid, as well as assure that our own buildings and their occupants are made as secure as possible against such hazards.

Early in the 1970's, motivated by the damage sustained by highway bridges during the 1971 San Fernando, California earthquake, the FHWA and the California Department of Transportation (CALTRANS) began exhaustive studies into the seismic performance of bridges, and began developing specifications to make them more earthquake resistant. Basic earthquake engineering research was sponsored and conducted by the FHWA, CALTRANS, the National Science Foundation (NSF), the National Institute of Standards and Technology (NIST) and the U.S. Geological Survey (USGS). Basic research was completed by 1977. The FHWA itself sponsored approximately $3 million of research on this topic.

In 1977, the FHWA initiated a study entitled "Bridge Seismic Design Guidelines" to: (1) evaluate then current criteria used for seismic design; (2) review recent seismic research findings for potential use in a new specification; (3) develop new and improved seismic design guidelines; and (4) evaluate the impact of the guidelines on construction and cost. The guidelines were completed in 1979 and ultimately adopted by the American Association of State Highway Transportation Officials (AASHTO) as a Guide Specification in 1983. [23 CFR 625.5(b)(5)] All States were thus provided improved criteria for increasing the seismic safety of highway bridges.

Yet, as witnessed by the damage caused by the Loma Prieta earthquake, and undoubtedly future earthquakes, we know that as we extend our knowledge about seismic strengthening, these criteria can be further improved. The principle source of this information is the work conducted under the auspices of the National Earthquake Hazard Reduction Program (NEHRP).

Mr. Chairman, your letter of invitation also asked us to address the vulnerability of pipelines. The pipeline system in the United States includes approximately 450,000 miles of transmission pipelines, of which 295,000 miles are for natural gas and 155,000 miles are for petroleum. Transmission pipelines are constructed and financed entirely by the private sector.

In 1970, safety regulations were promulgated by the Department of Transportation covering the operation and maintenance of transmission pipelines and the design and construction of new pipelines. The design regulation included a requirement that the design of new pipelines must take into account external loads, i.e., earthquakes. A majority of today's pipelines, however, were constructed prior to 1970.

During last October's Loma Prieta earthquake, there was no failure of natural gas or petroleum transmission pipelines in the affected area.

Natural gas distribution systems are more often subject to damage during an earthquake. Cast iron mains or service lines are particularly susceptible to failure because of their brittle nature. The Marina District of San Francisco experienced considerable damage to cast iron pipes. In contrast, the Palo Alto Municipal System, constructed of steel and plastic pipeline, suffered little damage. As a result of replacement programs, cast iron pipe is being slowly replaced in distribution systems through substitution of steel or plastic.

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Returning to the discussion of the needs of the overall national transportation system, we note that buildings and structures may be made more secure against earthquake damage through two methods: a) designing-in seismic strengthening before construction, or b) retrofitting. The first of these is usually far more efficient, but still can add 3 to 5% to construction costs for a typical building in a high risk area. The second, retrofit, tends to be very expensive, but in some applications can be cost-effective. In the Bay area, a number of the retrofitted highway structures performed well in resisting earthquake damage. Many lives were saved because CALTRANS had developed a program to identify and prioritize its seismicly vulnerable bridges and had already expended more than $60 million on implementing their retrofit program.

A number of earthquake-prone localities (e.g., California, Alaska) have for years incorporated stringent seismic protective features in their local building codes. It is now becoming recognized, however, that although far less seismicly active than the West, an earthquake in certain areas of the East could be more destructive, because:

(a) the composition of the earth's crust is such that the damaging seismic waves travel for far greater distances, and

(b) many Eastern cities, having not experienced a major earthquake in this century, have not required seismic strengthening in their local building codes.

It must be recognized that since not all geographical areas are equally seismicly active, constant trade-offs must be made within each region, matching the level of hazard anticipated at a given locality against the cost of risk reduction for facilities there. An additional complicating factor in establishing improved seismic safety in new buildings is that there are several major building codes in accepted use throughout the country, each with different seismic standards. One result is that with the exception of the highway area, DOT-sponsored projects have not been treated consistently regarding measures to protect against seismic vulnerability.

In the Department, we have been seeking means by which proactive work such as that by FHWA could be generalized to all of our constituency groups. By our constituency groups, I include not only our grantees, and the interests they serve, but also those in the private sector, who build and operate transportation facilities, and for whom we have safety regulatory responsibilities. In January, Secretary Skinner instituted the following four initiatives for the Department of Transportation, which although modest, would help us move forward in those areas.

1. Seismic Design Awareness - This effort represents an extensive education program for our constituencies and our grantees to identify specific measures that can reduce vulnerability and describe where they are appropriate. Much research has been done in the last 15 years and the lessons learned from recent earthquakes have been documented. For example, earthquake related highway bridge research conducted by FHWA and CALTRANS has definite application to the design and performance of mass transit and railroad bridges. Building related research conducted by or for NIST and NSF has application to DOT facilities. This existing information is fragmented, however, and we are now in the process of combining it in summary form into a transportation context, applicable to specific modal operations.

Concurrently, we are working on the development of technical sessions on earthquake design measures for transportation facilities in various constituency conferences, including those sponsored by the Transportation Research Board, the

American Public Transit Association, and the American Society of Civil Engineers. These fora provide DOT the opportunity to alert and assist managers and planners in the development of projects, highlighting those safety measures that are available and appropriate, to deal with the consequences of major earthquakes, especially in the eastern part of the United States.

2. Development of Uniform Standards for DOT Programs - A long range Department objective is the establishment of a uniform Department philosophy for seismic design. This will provide the technical underpinnings for both safety regulation and for guidance to our grantees on building standards, specifications, design criteria, and construction practices. These will draw on the quality material prepared by the ICSSC and will in many cases exceed the current local building codes, particularly in certain Eastern cities. These requirements must be judiciously imposed -- overly stringent designs where they never will be needed can be just as wasteful as future losses where they should have been employed.

3. Development of Retrofit Policy - Although most retrofit projects are expensive, there are some cases where low cost improvements to existing buildings and structures operated by DOT constituents would be warranted, (e.g., a $20,000 expenditure can add considerable protection against collapse of a bridge span and thus save lives). Again, fragmented information exists for retrofitting concepts on buildings and transportation structures, but to be of use to our constituencies, existing information must be collated into policy guidance on where to encourage their use. Part of this effort includes evaluating how our present body of knowledge can be augmented with additional research and experimentation to develop more model applications.

4. Assess Our Own Facilities and Functions - The Department is taking an inventory of its own significant buildings and structures to assess their seismic vulnerability. The assessment includes consideration of the number of occupants, the criticality of the functions which they house, their geographic region, and their construction type, to identify those with the highest priority for seismic strengthening. The Federal Aviation Administration has developed a computer program which is being used for the department-wide seismic vulnerability assessments. The identification of the installations of possible concern should not be too costly. Later, the most critical problem installations will have to be evaluated on-site to identify appropriate corrective action.

I would like to conclude on the note that when a major earthquake occurs, transportation systems and services have an importance that goes far beyond their everyday function . If the transportation facilities are able to withstand destructive tremors and continue operations, this will have benefits far beyond the importance of any single building, airport or bridge. The ability of utilities, communications, hospitals, supply depots and key government buildings to respond in the wake of a major earthquake's devastation, to sustain and to assist rescue and relief efforts, and to assist subsequent economic recovery, will depend directly on the resilience we have built into the transportation system.

That concludes my prepared testimony Mr. Chairman, and I would be pleased to answer your questions.

Senator GORE. I have just a brief question before recognizing Senator Danforth. Secretary Skinner was in charge of coordinating the Federal response to Loma Prieta.

Mr. TRILLING. That is right, sir.

Senator GORE. Will he be in charge of the next earthquake?

Mr. TRILLING. Secretary Skinner was tapped in the first place because there was not a FEMA designate at that level and secondly because there were a lot of transportation functions which had been affected.

Senator GORE. I want to make that point. The Secretary of Transportation was put in charge of coordinating the Federal response because we did not have a Director of FEMA. It has been 16 months—16 months since the last Director of FEMA announced his resignation, and we still do not have a successor. If there is another earthquake, will it automatically fall to the Secretary of Transportation? Will there be a lottery to see which Cabinet Secretary has to quickly come up to speed on earthquakes, or what will the procedure be? Is Secretary Skinner prepared to be in charge of the next one?

Mr. TRILLING. Secretary Skinner is prepared to respond to any emergency that comes up.

Senator GORE. Of course, and I understand that, and I think—I have great respect for him, and the point of the question is not in any way aimed at him. You understand what I am asking.

But it is a serious question, too. Has the Department of Transportation been notified that pending the selection of a new head of FEMA that the Secretary of Transportation is formally in charge of coordinating our response to the next earthquake?

Mr. TRILLING. No. I do not think there has been anything that formal.

Senator GORE. So it is going to be an ad hoc kind of arrangement? We do not know who will be in charge?

Mr. TRILLING. Well, I think I would like to let the representative from FEMA answer that, if I might.

Senator GORE. Now, in fairness there has been a report that FBI checks are being conducted on someone who may or may not be appointed, but it has been 16 months. It has been 16 months, and I think it is fair to make that point.

Anyway, I have a whole series of questions here, but I am going to hold off and recognize Senator Danforth.

Senator DANFORTH. Mr. Chairman, thank you very much. Thanks to each of the members of the panel for your testimony. A number of specific recommendations have been included in the testimony for what we should be doing. Are these controversial recommendations, or when you heard what your fellow panel members were saying, was there pretty much universal agreement about what we should be doing?

I mean, for example, Mr. Ross, you made some specific recommendations and Dr. Beavers made some other specific recommendations. Is this a matter of Congress calling for legislation based on the recommendations? Is this a matter of Congress sifting out the good from the not-so-good recommendations, or is there a consensus that there are certain things that we should be doing?

Mr. Ross. Senator Danforth, certainly in the recommendations I made, they basically came from the State Directors of Emergency Management across the country, and then of course from more specifically the CUSEC Board of Directors, which are the State Directors of the seven States of CUSEC, and then from my own State maybe more specifically.

There was a thread, or a continuum, between all of us. Of course, I come from the emergency management discipline, the lay discipline, so to speak, that goes out and fights—actually fights the wars, but we certainly discuss these issues. We meet often. I would say that basically there is general agreement about even the recommendations that I made, but I would certainly in regard to——

Senator Danforth. Do you agree with the other witnesses?

Mr. Ross. Yes, sir. Certainly in regards to building codes, a battle that I have long fought in my own State, and as you well know, Senator Danforth, we have no building codes—State building codes in Missouri, but we are moving forward insofar as specific legislation is concerned to deal first with the school issue and then with other public and private building issues.

Senator Danforth. As far as Congress is concerned, I take it that even if Congress were to pass Senator Gore's bill, still this panel would suggest that there are other things we should be doing, and I was wondering how difficult it would be for us to comb through your various suggestions and come up with whatever legislation we should be doing.

I mean, we do not want to get bogged down into all kinds of arguments among experts. Would it be a fairly simple matter for us to put together a consensus position of what else Congress should be doing?

Mr. Beavers. Well, I am not sure. I do not know how Congress works that well, myself.

Senator Danforth. I am not asking how Congress works. All I am asking is—is the community of experts in agreement as to what else we should be doing, or is this a question where if you asked 100 experts you would get 100 different glosses, and there really is not any consensus?

Mr. Beavers. With respect to the recommendations that I have heard here this morning and the ones that I made, Mr. Danforth, I believe—well, first of all, the recommendations I have made are very similar to the recommendations that have been made by the agencies, the associations that I represented here today. The Earthquake Engineering Research Institute, the American Association of Engineering Societies and the American Society of Civil Engineers.

For example, I know that the experts, including the agencies, are for increased funding. That was my first recommendation, that it be increased to $200 million.

Senator Danforth. You can be sure of it. Never in the annals of the Commerce Committee is there a record of anybody asking for less than increased funding.

Mr. Beavers. I think there is general agreement with the recommendations I made on the expert review panel on the NIST. They have been in my opinion severely underfunded to the point where some of the experts wonder why they are in the program at all, because the just cannot do the job with the funding they have had, and that is why I personally feel that their funding should be increased.

Senator DANFORTH. Dr. Beavers, I appreciate your testimony. What I am asking is, in listening to each other and what other people are saying, are we going off in 100 directions, or is there basically a common view?

Mr. BEAVERS. There is only one recommendation that I had that might be controversial, and that had to do with the oversight commission, and that would only be controversial from the standpoint of the agencies, and you can understand why that would be. But that has been recommended by the expert panel. It is supported by the Earthquake Engineering Research Institute.

Senator GORE. Would the senator yield?

First, for the record, my colleague has been very generous in referring to the Gore bill. I want to correct the record. It was the Gore-Danforth Bill, S. 1062, and I think it might be useful for us to let you in on the fact, and the other witnesses in on the fact that we are actively looking at ways to improve it.

I might suggest that just as we are combing through the suggestions that have been made, I might suggest we hold the record open so that if any of these witnesses today take strong exception to any of the suggestions made by other witnesses that you forward your comments to the Committee for inclusion as a supplement to the record of this hearing.

Please keep in mind that if you do not, suggestions that seem good and are consistent with the '87 expert review panel report and other authoritative documents may very well show up in subsequent legislative proposals, and I think the odds of passing measures are increasing as more people look at the need for this.

I appreciate my colleague yielding.

Senator DANFORTH. Mr. Ross, let me ask you another question obviously of selfish concern. There are various degrees of earthquakes, and a number, I think, have already occurred on the New Madrid fault. I think every year a number occur there. What would be the size of an earthquake on the New Madrid fault which would cause a disaster? How big would it have to be to be disastrous?

Mr. ROSS. Senator Danforth, let me say first there are virtually earthquakes daily along the New Madrid system. Those that are noted by the media are those usually in the 3.5 and 4 range, but really there are daily.

Second and more importantly, an earthquake in the magnitude of 6.5 to 6.7 at the north end of the New Madrid system could be quite damaging certainly even to areas of St. Louis. Moderate damage, maybe even more than moderate damage—some similarity maybe to what we saw in Loma Prieta.

My understandings are that as we would move that epicenter south closer to Memphis that we then even move into a serious situation insofar as Memphis, more serious than we were talking about with St. Louis. But we are talking a serious earthquake, serious damage in the case of Memphis and then, of course, the other communities and rural areas that are adjacent to that epicenter.

Senator DANFORTH. Would you say 6.5 to 6.7 then in that area would be a very serious earthquake?

Mr. Ross. It could be very serious, Senator. We seem to focus so much media-wise on earthquakes that are in the 7 or greater range. But the fact is if we look at the history of earthquakes around the planet earth for the last decade, that many have created havoc in the range of 6 and 6.5 and maybe even less than 6 in a few instances.

Senator Danforth. Do you know the probability that an earthquake would occur in the New Madrid fault in the 6.5 to 6.7 range or above in the next 20 years?

Mr. Ross. I'm sorry, Senator. Do I know the probability? Is that your question?

Senator Danforth. Right.

Mr. Ross. Well, yes, sir. And you have repeated it several times earlier this morning.

Senator Danforth. No. That is east of the Rockies. But I mean a major eathquake in the New Madrid fault itself. What I am talking about is, to you it would be a disaster if it is, say, 6.5 or above?

Mr. Ross. Yes, sir. Really we are probably talking about 60 percent probability.

Senator Danforth. 60 percent probability that in the New Madrid fault there would be an earthquake of 6.5 or above?

Mr. Ross. Yes, sir.

Senator Danforth. In the next 20 years.

Now, would you give a grade to our degree of preparedness for that eventuality?

Mr. Ross. Senator Danforth, of course that is very difficult because it is a multi-disciplinary issue. It is multi-faceted, but our grade right now overall on an academic scale would probably be in the C range. But, of course, we have grown in our capabilities dramatically on an empirical sort of a basis over the last five or six years we have played a lot of catch-up. We have copied, plagiarized a great deal from California obviously, certainly Japan and other countries as well, but mostly California.

California did not really begin their efforts seriously until 1933, some 26, 27 years after the 1906 earthquake. That took a relatively minor earthquake in Long Beach in 1933, I believe, a 5.7 earthquake of that range, which destroyed many of the school building in Long Beach to even bring the citizens of California, shall we say, to their senses on this issue.

So we have been trying to play catch-up. It has been slow. I do not want to overemphasize our accomplishments in either my state or Tennessee or Kentucky, Illinois, Indiana or any of the other states across this country. All of us have had one planner. There are those who think that maybe we have had half a dozen or whole teams of experts working on our staffs. We have not. You heard in my formal testimony that my staff, my personal staff is growing.

Senator Danforth. So if you were assigning a grade, it would be about a C?

Mr. Ross. I would say about a C, yes, sir.

Senator Danforth. Now, let me just rephrase the initial question.

It is your judgment that there is about a 60 percent likelihood that there may be a serious earthquake—that is 6.5 or over—in the New Madrid fault within the next 20 years, and a 6.5 would likely cause what kind of damage in St. Louis? And I know you could say depending upon this and that, but could you just give me a rough estimate?

Mr. Ross. Well, again considering that the epicenter is on the north end of the fault up near Cairo, well certainly the unreinforced masonry buildings that we see in the older sections of St. Louis are in certainly considerable danger of major damage in that case.

Unfortunately many of the schools in St. Louis, the older schools meet that unreinforced masonry.

Senator Danforth. Would schools likely collapse?

Mr. Ross. Schools could conceivably collapse, yes, sir.

Senator Danforth. Would bridges collapse?

Mr. Ross. There is that possibility. We have some concerns. As a matter of fact, our highway and transportation report, the Missouri State Highway and Transportation Report will be out very shortly discussing those issues, and we will have a better feeling as to their thoughts and their research, their findings.

Senator Danforth. Would it likely cause deaths in the hundreds?

Mr. Ross. It certainly could very well do so, sir.

Senator Danforth. The thousands?

Mr. Ross. Well, we are about to have placed in our hands a study that is about to be completed on the totality of the St. Louis situation.

What I have seen in the drafts are numbers in the—maybe in the hundreds with a 6.5. Now, certainly——

Senator Danforth. This is just in the greater St. Louis area?

Mr. Ross. Yes, but certainly as——

Senator Danforth. And then when you get to Sykeston and other outlying areas——

Mr. Ross. Well, certainly, again there could be those same sorts of building would suffer grievous damage and certainly casualties again could be considerable.

Senator Danforth. Would your best guess be that in the 60 percent eventuality that this comes to pass that there would be thousands of deaths in our state?

Mr. Ross. Not at 6.5, sir. My best evidence would indicate probably hundreds. But as we move on into the 7 or 7.5 range, then we are getting into four figures.

Senator Danforth. Into thousands?

Mr. Ross. Yes, sir.

Senator Danforth. Of deaths?

Mr. Ross. Yes.

Senator Danforth. And much, much property damage?

Mr. Ross. That is correct. As a matter of fact, again, depending upon the epicenter and the severity we are again probably talking billions, maybe even in the worst case hundreds of billions of dollars throughout the area.

Senator Danforth. What was the famous—when was that, 1811?

Mr. Ross. Yes, sir, the winter of 1811 and 1812, the series.

Senator Danforth. What was the magnitude of that?

Mr. Ross. Interpolated to have been in the 8.1 or 8.3 range. I believe 8.3, and I will let my experts to my left correct me, but I believe there were at least three in the 8 range.

Dr. **Beavers**. There were three and on the Richter magnitude scale there is still some debate on that the estimates are, but I have seen them size 8.7 for the one that occurred in February, the one in January around 8.4 or 8.5, and the one in December, which was the first one, around 8.4 or 5.

Senator **Danforth**. Is there any likelihood that there would be again, say, an 8.0 or more earthquake in the New Madrid fault?

Mr. Ross. Well, again, the gentlemen to my left would and the earlier panels would probably say that that is remote at this time, that the return on an earthquake or a series of earthquakes of the magnitude is remote.

Senator **Danforth**. But 6.5 is 60 percent you believe?

Dr. **Beavers**. That might be on the high side of 6.5. I think Dr. Arch Johnson's studies have shown that for a magnitude around 6 to 6.5 that it is between 40 and 60 percent, so I think it is reasonable to say 50 percent.

Now, on your 8.5 I think Dr. Johnson's study show about, if my memory serves me right, 1 percent chance in the next 20 years or 25 years, something like that of an 8.5.

Senator **Danforth**. But if it were to occur, that 1 percent would be unbelievably devastating, right?

Mr. Ross. That is absolutely correct, like nothing we have ever seen in this country.

Senator **Danforth**. Like a nuclear bomb?

Mr. Ross. Yes, sir.

Senator **Danforth**. How about in the 7 range? What would be the probability of, say, a 7 or 7.5?

Mr. Ross. Well, certainly the damage grows dramatically and the costs grow, and the casualties grow.

Senator **Danforth**. But what would be the probability of somewhere between 50 percent and 1 percent?

Dr. **Beavers**. I think it is on the order of about 20 percent if my memory serves correct.

Senator **Danforth**. And what would be the degree of damage in, say, the St. Louis area?

Dr. **Beavers**. You are going to have significant damage, especially if it occurs on the north end.

Senator **Danforth**. Thousands of deaths would you say?

Mr. Ross. No, not that many, but certainly hundreds again and getting up into the thousands.

Senator **Danforth**. Then when you get down into Cape Girardeau and Sykeston?

Mr. Ross. Certainly, sir, right on down.

Senator **Danforth**. You are not even crossing the river into Tennessee yet, but you would have thousands of deaths within our state alone?

Mr. Ross. We certainly could have, sir.

Dr. **Beavers**. What you have got to think about, too, is that if for those cities close to the New Madrid even or to the event, like New Madrid, like Cape Girardeau you could have major devastation at a magnitude 7, 7.5 or 8, just major, everything wiped out.

I think in Paducah, Kentucky, which is about 45 miles from the New Madrid fault if you had 8.5, something on the neighborhood of 6,000 buildings are totally destroyed is the estimates that I have seen if my memory serves me correctly.

Senator **Danforth**. Mr. Chairman, you have been very generous with your time, and I appreciate it, and I appreciate the testimony of Mr. Ross and the rest of the members of this panel. You have underscored the urgency of this issue. I hope that we in Congress can do whatever we should do to be helpful, and I also hope that all of us, at the state and local levels, without waiting for Congress—because you can wait around forever for Congress to do anything. So please do not wait for us. Do not wait a minute for Congress to do a thing.

I would hope that you would do everything you possibly could do to anticipate what could happen. Thank you very much. Thank you, Mr. Chairman.

Senator **Gore**. Thank you very much, Senator Danforth. I look forward to continuing to work together on this.

I only have a few questions that I will present to you openly. I have others that I will give to you in writing and ask you to respond to for the record.

Dr. Whitman and Dr. Beavers, how would you assess the job the Federal Government has done to ensure that the buildings and facilities it owns, leases and regulates are not vulnerable to earthquakes? Which agencies have done a particularly good job? Which have been slowest to face the problem, and what problems do you think need to be addressed first?

Dr. **Beavers**. Well, this is my opinion, of course, but obviously as far as what the agency—and this is other than the four agencies involved in the NEHRP program—the NRC has done the most in the earthquake business, if you will because of the nuclear power plant issue. The Department of Energy has done a lot in the last ten years with respect to their facilities, primarily critical facilities.

About some of the other agencies I do know the Department of Transportation has been doing some things. I am aware of what the Navy has been doing. But to really get a good handle on it from where I sit is very difficult.

As I pick up the NEHRP report to Congress I notice that a lot of the agencies who are members of the Inter-Agency Committee on Seismic Safety do not have reports, and as far as office buildings and existing office buildings, my—in a gross sense virtually nothing is being done.

Senator **Gore**. Dr. Whitman.

Dr.**Whitman**. Well, I have very little to add to that. I think my impression is very similar to Dr. Beavers'. I would just add in addition that I know of the efforts of the Corps of Engineers of the Army and of the Bureau of Reclamation, as well of course as state organizations, and especially in California, to examine the safety of dams that are under their jurisdiction. A number of problem dams have been identified and in a number of these cases, at considerable expense, efforts have been made to make them more resistant to earthquakes.

Senator **Gore**. Mr. Ross, in your testimony you make it clear that the national earthquake program is underfunded and that the earthquake threat is so serious that we need to allocate more resources to address it.

In the last ten years earthquake researchers have found that the threat of earthquakes is greater and more widespread than had been thought, and yet in those same ten years the funding levels for the programs to predict and mitigate earthquakes has fallen by more than 35 percent in real terms.

Why do you think this has been the case? How has this affected your earthquake program in Missouri, and what would you do with increased funding?

Mr. Ross. First, Senator, the first part of your question, obviously the funds have not grown. That has no doubt been reflective of declining assets at the Federal level or whatever. Certainly most of the work over the years had been done in California, and I mentioned that we have, all of us—all of us have across the United States are in fact grateful to the State of California for all the work that has been done there, for the start-up for our programs.

But the fact is that in the few years that the rest of the states so to speak have been involved in serious programs that the funding has been very modest. We are talking about maybe $30,000 to $40,000 of Federal funding to each of these states per year. We have made that $40,000 go a long ways. It has been multiplied many times over in many ways, but a very modest funding.

I would say on the side of the states or on behalf of or maybe negatively insofar as the state legislatures are concerned that many of them have been very slow to act.

You will note in the case of my own state that I am very up-front about this. It took until last year for the state legislature of my great state of Missouri to in fact match the federal, the very modest federal funding, but they did so, and they are moving out very rapidly in 1990 and 1991, and any Federal funding of that we can be allocated will be matched and can be matched by my state legislature now. They are believers now. Missouri is the ""show me" state. Missouri is not the only ""show me" state. It is the only one that claims to be a ""show me" state, but we have been shown, and we are moving forward smartly, and I am very proud of that.

Senator Gore. Well, thank you very much.

I have a number of questions for each of you on other related subjects, but we have run overtime.

I want to close by thanking each one of you for your willingness to come here today, and you have helped significantly in our effort to arrive at a better understanding of how we can proceed responsibly and efficiently. And, as I mentioned, I anticipate that the testimony here today along with the expert review and other information will serve as a basis for new initiatives to upgrade what we are doing to prepare for earthquakes and better predict earthquakes.

And so I do want to thank all of you again, and with that our hearing will be adjourned.

[Whereupon, at 12:32 p.m., the subcommittee adjourned, subject to the call of the Chair.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

PAUL SIMON

United States Senate
WASHINGTON DC 20510

March 29, 1990

Mr. Chairman:

I want to thank the distinguished Chairman, Senator Gore, and the other members of the Subcommittee for including my remarks as part of the hearing on this important program. Although I am not a member of the Science, Technology and Space Subcommittee, I am concerned about the effective operation of the National Earthquake Hazards Reduction Program. I applaud the Chairman's activities in this area and I am grateful for his leadership.

Although attention has focused traditionally on the West Coast as being the only active earthquake zone in the United States, I unfortunately can report that California is not alone. As the Chairman well knows, the New Madrid fault (the active part) starts west of Memphis near Marked Tree, Arkansas and extends through Missouri and Cairo, Illinois. While we have experienced relatively little earthquake activity recently, the history of the New Madrid fault belies comfort. In 1811 and 1812, the fault experienced earthquakes so severe they were felt as far away as Boston. Although severe earthquakes occurred once again in 1895, the fault has been relatively quiet since that time. Experts predict that moderately strong earthquakes occur in this region every 75 to 100 years; obviously, the New Madrid fault is overdue. A recent article in State Government News estimated that on a scale of 0 to 100 for preparedness, San Francisco ranks 90, Armenia ranks 0, and the central United States ranks between 10 and 20. This is clearly unacceptable.

Because of the inactivity of the fault in recent memory, my constituents are used to looking to the skies and the rivers for natural disasters, but not necessarily under their feet. There is, however, a growing awareness that the fault could be triggered at any time. Beginning early this year, the State of Illinois has been conducting statewide meetings to determine the state's preparednesss for an earthquake and what steps can be taken now to minimize potential damage. A report is scheduled to be made public, with the Task Force's recommendations, on April 2. I believe Illinois is to be commended for taking these steps and I look forward to reading their report. Illinois, however, needs the assistance of the federal government and its expertise in these matters in order to adequately prepare itself. The Earthquake Hazards Reduction Program, with the strengthening language added by Senator Gore, will provide the assistance necessary to help Illinois plan effectively. I urge the Subcommittee to move quickly on the reauthorization of this important program.

Again, I thank you for giving me the opportunity to present my views. I look forward to working with the Subcommittee in the future.

to: **Senator Albert Gore, Jr.**
Chairman, Senate Subcommittee on Science, Technology and Space.

Mr. Chairman:

I. INTRODUCTION:

My name is John Franklin Kenney. I am the president of Gas Resources Corporation; by original training I am a physicist in which field I hold a doctoral degree from the Massachusetts Institute of Technology. Gas Resources Corporation is a small independent oil and gas company. Our company has for more than 4 years been intensely engaged in a project involving earthquake prediction. We bring to this project not only our years of experience in the petroleum industry but also thorough knowledge of the processes which trigger earthquakes gained by understanding of the petroleum operations which do so. Our research has taken the senior personnel of our company to Europe, Japan, China and the Soviet Union in the course of the investigations connected with this project. As a result of our intensive, directed research in this area combined with our industrial experience, we possess expertise perhaps unique in this unusual area of human activity. [This observation has been demonstrated by our having brought to the attention of this Committee the examples of the scientific measurements which could have predicted the Loma Prieta earthquake, - which measurements had been previously unrecognized even by the director of the United States Geological Survey.] I add our observation that the greatest expertise in the field of earthquake prediction is to be found outside the U.S.A.; for scientific policy has neglected the development of the skills and disciplines which have been demonstrated elsewhere to be most useful for earthquake prediction.

All of our company's research into earthquake hazard reduction has been carried out entirely at our own expense and without public money.

The mission of our company's project is to provide timely warning of impending earthquakes in order that government agencies charged with civil defense and safety matters can take appropriate action.

Our scrutiny and evaluation of the expenditures of the tax revenues appropriated under the National Earthquake Hazard Reduction Program (NEHRP) Act have compelled the conclusion that a large portion of such funds are being spent inefficiently upon academic research which past experience has shown to have little more than marginal benefit for the reduction of earthquake hazard.

II. PERSPECTIVE:

There are two areas of activity which reduce earthquake hazard:

1. The development of civil engineering skills for the construction of earthquake resistant buildings and structures, - combined with stringently enforced zoning and building codes; and

2. The development of warning systems for impending earthquakes, - combined with appropriate civil defense policies.

to: **Senator Albert Gore, Jr.**
Chairman, Senate Subcommittee on Science, Technology and Space.

It should be noted that these two activities are almost entirely independent of each other. Conduct of the first type of activity has almost no influence upon the second, and vice versa.

III. REVIEW AND CRITIQUE OF THE TAX EXPENDITURES TO DATE IN THESE AREAS:

The funds which have been appropriated under NEHRP have been partly well spent, and partly poorly so. Of the two areas of activity which contribute to the reduction of earthquake hazard, the first has been addressed satisfactorily, and the second has been, and is, inappropriately neglected.

1. The funding for civil engineering research directed toward the development of earthquake resistant structures is mostly well spent and should be continued.

   Similarly, the spending for assistance in legislating zoning and building codes is well directed.
   However, oversight should be exercised to assure that money is not wasted "reinventing the wheel". During the Hearings, there were several instances of requests for funds for research in civil engineering connected with development and testing for earthquake resistant structures which has already been carried out in Japan.

   Furthermore, it is probably not necessary to spend more funds upon seismology studies intended to identify (or hypothesize) more faults or individual earthquake prone areas.
   No county, city or state is going to legislate a multitude of building codes. Once a given area has been identified as being subject to earthquake hazard, the strictest building code should be applied uniformly throughout the region. Expenditure for such as fault identification should be subordinate to either civil engineering research or development of prediction and warning systems.

There needs little to be said upon this subject other than to note, again, that this area of research and development is independent of that for warning and civil defense measures for impending earthquakes.

2. Funding for the development of warning systems for impending earthquakes has been neglected. This neglect cannot be excused because practical earthquake prediction and warning has been demonstrated in other countries, such as China.
   By consequence, the development of civil defense procedures which would be appropriate for circumstances of warning for impending earthquakes has also been largely neglected.

On this subject much needs to be said. This neglect, and the inappropriate and mostly ineffective expenditures of the funds available under NEHRP, are the subjects of most of this testimony.

to: **Senator Albert Gore, Jr.**
Chairman, Senate Subcommittee on Science, Technology and Space.

The spending of that part of the funds appropriated under NEHRP which has been directed toward pure scientific research has been restricted almost entirely toward the limited perspectives of seismological investigations. Such seismology research is of minor value for any reduction of earthquake hazard. The funds of NEHRP ought not to be used to support academic seismology faculties for activities which deserve to be part of a university research budget, not part of a public safety Act.

More unsatisfactory has been the consistent refusal to spend funds of the NEHRP toward practicable earthquake prediction, - which discipline involves earthquake geochemistry and several other disciplines, not seismology. However, the techniques of earthquake geochemistry and certain physical measurements are capable of predicting earthquakes accurately and within a usefully short time span, say, 24-72 hours. These techniques have been demonstrated in China, the U.S.S.R. and even in here in the U.S.A. Yet the use and development of these techniques is being neglected by the current applications of the NEHRP.

IV. EXAMPLES OF THE NEGLECT OF RESEARCH AND DEVELOPMENT IN THE FIELD OF EARTHQUAKE PRECURSORS GENERALLY AND OF EARTHQUAKE GEOCHEMISTRY SPECIFICALLY.

1. The lack of funding and general disregard for earthquake precursor studies prior to the Loma Prieta earthquake last year.

We have already brought to the attention of this Committee the observations of the geochemical earthquake precursors observed by Dr. Reimer of the United States Geological Survey through the monitoring of Helium gas and by Dr. Fraser-Smith of Stanford University through monitoring low frequency electromagnetic radiation. Both of these techniques are ones which have been used successfully in Asia for predicting earthquakes.

Dr. Reimer has had the funding for his work consistently reduced during the past several years, and for that reason he had only one (1) operating site in the northern California area where it could have predicted the Loma Prieta earthquake. Furthermore, the expenditures for funding under NEHRP for this research has been so inadequate that Dr. Reimer was unable to conduct his monitoring in "real time" as would be possible with an appropriately telemetered system. Thus any warning which the detection of Helium gas precursors might have provided was inevitably foregone. I understand that, in the months following the Loma Prieta earthquake, Dr. Reimer has had not only not had his research funding increased but that such has been cut further.

Dr. Fraser-Smith has had no funding whatever through NEHRP.

The failure to fund the work of Dr. Reimer, Dr. Fraser-Smith and of the other persons working in the field of earthquake precursor detection is manifestation of a systematic fault in the way in which the tax revenues authorized for NEHRP have been, and are, allocated, which are described in the next example.

2. The manner in which funds authorized under NEHRP have been, and are presently, allocated which excludes, or discriminates against, research in earthquake precursor detection.

In Announcement 7637, published by the United States Geological Survey and the National Science Foundation specifically calling for proposals for research connected with the Loma Prieta earthquake under the authorization of NEHRP, there were eight (8) different "Elements" (or academic disciplines) under which proposals could be submitted and would be considered.

One (1) "Element" involved "review of preparedness and response efforts" another involved "economic and social aspects". The former concerns civil defense measures which certainly must be part of any competent program for the reduction of earthquake hazard; the latter is of arguable benefit for reduction of earthquake hazard.

Three (3) "Elements" involved civil and structural engineering, also useful areas to investigate for the reduction of earthquake hazard and one which stands independently of the others.

Three (3) "Elements" specified "seismological" studies, or geological or geodetic studies relating to seismology.

Zero (0) "Elements" are designated for, or concerned with, earthquake geochemistry in that Announcement. Nowhere in the Announcement is the phrase "earthquake geochemistry" to be found. Similarly, there is no mention of geochemistry, or geochemical precursors in that document.

Similarly, the Announcement 7622 from the United States Geological Survey calling for proposals for research under NEHRP is also entirely lacking in any recognition of earthquake geochemistry and contains no "Element" specifying research in that area. All of the research funds not directed toward civil engineering have been given over to exercises in academic seismology research which has at best only tenuous connection with any reduction of earthquake hazard.

A direct example of this misapplication of the NEHRP funds is the specification in that Announcement for the type of research for which support will be given in the area of earthquake prediction: "analyzing and evaluating seismicity data ...", - and this despite more than 20 years worth of demonstration that such data does not render any predictive ability.

3. The exclusion of the research scientists in earthquake precursor and prediction work from the funding authorized by Congress under NEHRP.

After the Loma Prieta earthquake, Senator Gore and this Committee authorized an extra twenty Million Dollars for research in connection with that event. Of that money, approximately twelve Million went to the United States Geological Survey. Of that extra twelve Million Dollars, the United States Geological Survey did not allocate so much as a single thin dime for research in earthquake precursor or geochemical prediction work. All of that money has been directed toward still more seismology related research. The scientists working in earthquake precursor fields have been entirely excluded from this funding.

to: **Senator Albert Gore, Jr.**
Chairman, Senate Subcommittee on Science, Technology and Space.

This use of public funds intended for the reduction of earthquake hazard is comparable to actions of a city government which lacked any fire protection services and spent its tax revenues intended for fire protection on academic studies involving combustion dynamics in a university laboratory instead of organizing proper fire alarm systems and hook and ladder companies and pumping teams.

This neglect of of the discipline of earthquake geochemistry is especially censurable because it has been application of that discipline which enabled the Chinese to predict, for instance, 4 out of 5 earthquakes of magnitude greater than M7 during the episodes of the Sungpan-Pingwu events. It has been also the application of this discipline which enabled Dr. Reimer of the United States Geological Survey and Dr. Fraser-Smith of Stanford to observe the precursors to the Loma Prieta earthquake. Yet neither of these men has received any support from the funds appropriated under NEHRP for their work; nor have any of the other competent geochemists in the United States Geological Survey or elsewhere been given support for their work. The disparaging attitude toward geochemistry, combined with a general lack of competency in earthquake geochemistry, has resulted in a neglect of those disciplines and techniques which have already demonstrated ability to predict earthquakes.

The American taxpayers have been spending approximately ten Million Dollars per year during the past twenty years for seismology research intended to develop ability to predict earthquakes. After twenty years and approximately a quarter of a Billion Dollars spent, the seismologists have not predicted a single earthquake. During that same period of time, the Chinese and others (including some Americans) have demonstrated the ability to predict earthquakes using other techniques, which are still being neglected in the U.S.A.

I urge that this Committee and Congress exercise its legislative oversight function to require the correction of this inappropriate expenditure of funds authorized under the NEHRP Act.

V. A FINAL CORRECTION TO SOME COMMON MISUNDERSTANDINGS ABOUT THE LOMA PRIETA EARTHQUAKE, AND ABOUT EARTHQUAKES AND PUBLIC POLICY GENERALLY.

In the aftermath of the recent Loma Prieta earthquake of Richter scale magnitude 7 which occurred in northern California last 17 October, there have been a number of incorrect statements made in the media to the effect that "... earthquakes can never be predicted ..., etc.," which we want to correct, as follows:

1.) The persons who were killed or injured when caught on the elevated freeways and the Bay bridge in California on 17 October (the date of the recent M7 Loma Prieta earthquake) need not have been at risk.

The knowledge and technology required to provide warning of impending earthquakes already exist. This necessary predictive ability has already been demonstrated, both here in the United States and in several foreign countries.

2.) If the government of, for example, China, had been in authority in California that week, that government almost certainly would have cleared all traffic off of the freeways and bridges 12-14 hours prior to the earthquake.

Taking the policies of the government of China as one example, in that country, the agencies responsible in China have achieved at times success rates in predicting earthquakes of 80% using very limited technology, and they have thereby saved (by their own estimates) between 30,000 and 60,000 lives during various periods as short as three years.

3.) Since we consider ourselves to have a superior form of government to that of China, we ought certainly to do at least as well in that area of public safety administration involving earthquake hazard.

4.) Next time the United States Government has got to do a better job of providing timely earthquake warning (and at least no better than the Chinese government).

I urge that your Committee take whatever steps needed to correct this past failure of the government to provide what ought to be a vital service for public safety.

EERI

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March 16, 1990

Honorable Albert Gore, Jr.
Committee on Commerce, Science,
and Transportation
SD-508, Dirksen Senate Office Building
Washington, D.C. 20510

Dear Senator Gore:

On behalf of the 1700 members of the Earthquake Engineering Research Institute, we are writing to express support for the reauthorization of the National Earthquake Hazards Reduction Program and appropriation of additional funds in FY 1991 for the program.

EERI is the principal, national, professional association of engineers, geoscientists, architects, planners, public officials, and social scientists concerned about earthquakes and their effects. EERI's unique interdisciplinary membership fosters communication among the disciplines and provides rapid transfer of new knowledge to design, practice, and policy. For the past four decades, EERI has provided primary leadership toward advancement of the science and practice of earthquake engineering and the solution of multidisciplinary problems to protect people and property from the effects of earthquakes.

Recognizing the threat of catastrophic loss of life and property posed by earthquake hazards in the United States, Congress enacted the Earthquake Hazards Reduction Program in 1977 and assigned the task of its implementation to the Federal Emergency Management Agency, the U.S. Geological Survey, the National Science Foundation, and the National Bureau of Standards.

The Loma Prieta earthquake of October 17, 1989, in the San Francisco Bay Area, again demonstrated the value of the NEHRP and the numerous state and local programs it has influenced in the past thirteen years. While it is recognized as the most expensive disaster in U.S. history, total loss of life and overall economic disruption in the San Francisco Bay area would have been much greater had basic and applied research not been incorporated into engineering design and practice. These research and application activities have led to improved codes, implementation of improved construction practices, and greater support for earthquake preparedness and public education. However, while we proudly claim a measure of success in the Loma Prieta earthquake, the great economic losses due to structural failure and business interruption caused by this earthquake demand that much more be done to prepare the nation to cope with larger, future earthquakes.

EERI fully supports the reauthorization of the NEHRP at an increased level of funding. The NEHRP Expert Review Committee recommended funding at a level of about $200 million per year distributed to the core agencies in the following amounts: USGS $80M; NSF/EAR $18M; NSF/ENG $66M; NIST $4M; and FEMA $30M. This distribution provides approximately $100M for earth science activities and $100M for earthquake engineering and implementation activities. The rationale for this distribution was weighed carefully by the Review Committee. The relative 50/50 split between earth sciences and engineering/implementation should be maintained for levels of funding less than $200M. The Review Committee recognized that both science and engineering researchers have a responsibility to translate their findings for more rapid application.

Unfortunately, while NEHRP funding levels have remained constant over the past thirteen years, inflation has, in actuality, significantly reduced available support for basic and applied research programs. As a result, earthquake engineering research programs are being reduced in size and fewer future professional earthquake engineers are being educated in our university system.

A balanced earthquake hazards reduction program needs both short-term and long-term basic and applied research. We believe that there is a need to further increase the transfer of existing and newly developed knowledge to professionals at the state and local levels. One of the most effective transfers of research knowledge into practice is through students who are employed by professionals and by direct interaction of these professionals in the research programs. This interactive cooperation of research and practice makes research more responsive to the needs of practitioners and more immediately useful to the profession.

EERI, the National Research Council, and other private, federal, and state agencies have had a long history of mutual cooperation in post earthquake investigations. The appropriation of special funds to perform these investigations has been excellent and has benefitted the earthquake community and the nation for many years. In the case of the Loma Prieta earthquake, USGS received $8M for earthquake investigations for the entire NEHRP effort. Of this $8M total, $1.5M was transferred to NSF for earthquake engineering post earthquake investigations, and $0.5M was transferred to NIST for post earthquake engineering investigations to support code development efforts. As a result, only 25% of the total post earthquake investigation funds were available for all engineering, social and economic research. We believe that post earthquake investigation funds, for all earthquakes, should be distributed to each of the agencies in a balanced manner and that the lead agency (FEMA) should ensure that investigations are fully coordinated.

With regard to future funding, it is apparent that considerable scientific information has been gathered over the past decade, especially in the Loma Prieta earthquake. Increased support is now needed to provide practicing engineers and other design professionals with improved design and analysis techniques to enable them to better utilize existing knowledge.

EERI's members are interested and committed to the goals of the NEHRP. They are widely skilled in all earthquake-related areas of scientific and engineering research, engineering practice, and implementation of earthquake damage mitigation actions. We would be pleased to identify experts to meet with you in Washington to discuss these issues in greater depth or to answer any questions you or other committee members may have.

Respectfully yours,

Board of Directors
Earthquake Engineering Research Institute

Susan K. Tubbesing
Susan K. Tubbesing
Executive Director

BOD:SKT:lb

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March 29, 1990

The Honorable Albert Gore, Jr.
Chairman
Subcommittee on Science,
Technology and Space
427 Hart Senate Office Building
Washington, DC 20510

Dear Mr. Chairman:

As the Subcommittee on Science, Technology and Space begins to consider reauthorization of the National Earthquake Hazards Reduction Program (NEHRP), I am pleased to convey the views of the American Society of Civil Engineers (ASCE) on earthquake engineering research funding. ASCE is the oldest national engineering organization in the U.S. with membership of more than 100,000 civil engineers.

ASCE supports and encourages legislation which accomplishes the following:

1. Increases basic research in earthquake engineering under the NEHRP;
2. Increases applied research, testing, and accelerated technology transfer of research results;
3. Adopts and enforces standards for seismic design and construction for new and existing federal buildings;
4. Adopts and enforces building codes and zoning provisions to incorporate improved seismic design and construction standards for new and existing buildings and lifelines by state and local governments and by industry;
5. Improves earthquake preparedness, particularly for building safety, lifeline systems and emergency response;
6. Increases public education about earthquakes and engineering concepts for hazard reduction;

7. Provides for stronger leadership, and improved interagency coordination in NEHRP;

8. Increases overall federal funding for the NEHRP.

Civil engineers are keenly aware of the devastating impacts associated with earthquakes. The NEHRP was created in 1977 to explore ways of reducing this devastation. However, despite continuing needs, funding for NEHRP has shrunk about 40% in real dollars since the late 1970s.

The terrible destruction caused by recent earthquakes in northern California, Mexico, and Armenia clearly illustrates the need for a strong NEHRP. ASCE stands ready to assist you in advancing the aforementioned legislative goals.

Sincerely,

John A. Focht Jr.

John A. Focht, Jr.
President

THE ROLE OF EARTHQUAKE MITIGATION TECHNOLOGY

Life, Safety, Structures, Contents, and Function

TESTIMONY

Hearings on

REAUTHORIZATION OF THE EARTHQUAKE HAZARDS REDUCTION PROGRAM

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE
SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

March 29, 1990

Dr. Robert J. Kuntz
President
California Engineering Foundation

INTRODUCTION

A predictable cycle of activity occurs after every major earthquake. Emergency preparedness systems are tested and found wanting. The print and electronic media move in to cover the disaster for the news hungry public. Political leaders visit disaster sites to express concern for the victims and to capitalize on media opportunities. Numerous bills are introduced into the affected state legislature to throw money at the problem. Universities and research organizations submit proposals for more studies on all aspects of the disaster. Then, media interest diminishes, and life returns to normal for those unaffected by the earthquake until another earthquake repeats the cycle. The cycle in California includes reducing earthquake hazards by adopting building codes and government response plans -- after an earthquake has occurred.

Earthquake hazards reduction programs historically focus on increasing protection of life and safety with building codes and government plans adopted after an earthquake. But, a new philosophy has emerged in California which is intended to protect life and safety and mitigate earthquake effects on structures, building contents, and function, which merits the attention of the National Earthquake Hazards Reduction Program. The philosophy is based upon new but proven seismic technologies, including base isolation.

BACKGROUND

Research was sponsored by the National Science Foundation in the late 1970's which permitted the Earthquake Research Center of the University of California, Berkeley, to explore a new concept in earthquake hazard mitigation called base isolation. This technology is a way of isolating structures from earthquake shock by placing specially designed pedestals, called isolators, between the structure and its foundation. Isolator design, analysis, and testing results indicated that base isolators, fabricated from laminated steel sheets and energy absorbing elastomers made from natural rubber, would reduce earthquake shock on building structures.

The California Engineering Foundation (CEF) felt that this technology should be illuminated to the principal organization in California responsible for policy planning in earthquake matters -- the California Seismic Safety Commission. The CEF arranged, with the assistance of then Assemblyman Don Rogers of the California Legislature, for a briefing of the Commission in 1981. The Commission Chairman, Mr. Robert Rigney, not an engineer, became convinced that base isolation merited further investigation.

Mr. Rigney was the Chief Administrative Officer for the County of San Bernardino in Southern California. The County had approved the design and construction of a new $38 million four story building called the Foothill Communities Law and Justice Center, and design was nearing completion. Mr. Rigney proposed to the County Board of Supervisors that the design be changed to incorporate a base isolation system, and the project was approved. One of the challenges faced by Rigney was professional and institutional resistance to using new designs not codified in building codes. Engineers and architects opposed the use of a new, unproven design in the building.

Skeptics became zealots as the design progressed. The facility was dedicated in 1985 and became the first seismically isolated building in the United States. It was fully instrumented with accelerometers by the Office of Strong Motion Studies of the Division of Mines and Geology of the California Department of Conservation.

Three earthquakes have occurred in the vicinity of the building, located in Rancho Cucamonga, since construction was completed, and all triggered the instruments. The largest and most recent occurred on February 28, 1990, near Upland, California. It had a Richter scale magnitude of 5.5, and the epicenter was about 7 miles from the Law and Justice Center.

According to the Office of Strong Motion Studies report of March 2, 1990, ground acceleration at the base of the building foundation was 0.16g, and above the isolators, 0.08g indicating the shock into the structure was halved in magnitude by the base isolation system. The acceleration of the building at roof level was 0.16 thus showing an amplification of the structure itself of 2.

Two other buildings in the vicinity of the earthquake were also instrumented. One was constructed with unreinforced masonry walls and the other was steel reinforced. The instruments in these structures indicated the ground shock, directly applied to the foundation, was amplified three times by the building structure resulting in an acceleration at roof level of 0.37g.

NEW APPLICATIONS OF BASE ISOLATION

Two additional structures using base isolation systems are under construction in Southern California: the new University of Southern California Medical Center and the Los Angeles County 911 Facility. The U.S. Office of General Services approved the use of a base isolation system in a Post Office building that was to have been constructed in the Los Angeles area, but this decision was vetoed by the Office of Management and Budget. Representative George Brown, of the House Science and Technology Committee, pointed out that the federal government is obliged under law to demonstrate new technology developed by the federal government. However, the OMB did not wish to deviate from standard design practice.

BUILDING CODES

Structural design must comply with building codes, including the Uniform Building Code and the California Building Code. Present codes dictate that a building should not be damaged in a minor earthquake, structurally damaged in a moderate earthquake, and not collapse in a major earthquake. There are no provisions in the codes that require protection of building contents and function. However, the Hospital Seismic Safety Act of 1972, written after the 1971 San Fernando earthquake destroyed two hospitals and damaged 14 others, states that hospitals are to remain operational, "as much as practicable," during and after a major earthquake. The "as much as practicable" clause provided sufficient escape from the legislative intent as to render the law ineffective.

NEW CALIFORNIA POLICY

Continued interest in earthquake hazard mitigation has been demonstrated by State Senator Don Rogers (R-Bakersfield), the only geologist in the California Legislature. In 1985, as an Assemblyman, he introduced Assembly Concurrent Resolution 55 requesting the California State Architect to explore new earthquake hazard mitigating technologies, including base isolation, to increase protection for building contents and function. Such studies were initiated.

Concurrently, the CEF continued efforts in earthquake hazard mitigation and planned to conduct a major conference on the subject. The objective was to examine the impedances to new earthquake hazards mitigation and increase understanding in the technical community about protection of structures, building contents, and facility functional capability during and after a major earthquake. The conference plan focused on earthquake hazard mitigation research conducted in the University of

California and the work being done on the Law and Justice Center.

Several attempts were made to identify a funding source to assist conference development and execution. Unfortunately, none was found. It seems that funds are available to conduct research but are not available to educate the practitioners to apply the findings to building design and construction. While additional funding for earthquake engineering research is clearly needed, there is also a need to transfer the results of that research to the engineers, architects, and policy makers who need it.

In 1988, the CEF determined that time was overdue to address the policy issues related to the application of earthquake hazard mitigation in buildings. The Foundation developed and convened a two day conference in January, 1989, involving specialists in design, seismology, engineering, construction, codes, insurance, public policy, and other areas related to the design, construction, and protection of buildings in seismically active areas. The purpose of the conference was to increase understanding of the risks and illuminate earthquake hazard mitigating technologies to protect structures, building contents, and function. The conference included two major components: education of the attendees and developing hazard mitigation policy recommendations.

Twenty recommendations were produced concerning state codes and policy, cost, insurance, education and research. Paramount in the conference findings was the necessity for the government to assume a leadership role in implementing new hazard mitigation technology in public buildings, with an emphasis on facilities performing critical functions, including: hospitals, air traffic control centers, fire control centers, telecommunications facilities, and others crucial to public health, safety, welfare, and good. The government should also create incentives for building owners to incorporate earthquake hazards mitigation technology in new buildings and retrofit older ones and make decisions based upon life cycle analysis not just initial design and construction costs.

Senator Don Rogers was one of the conference sponsors. At the conclusion of the conference, Senator Rogers assembled a task force with representatives from the CEF, the Structural Engineers Association, California Seismic Safety Commission, State Architect's office, Office of General Services, the California Council of Civil Engineers and Land Surveyers, University of California, and individual consulting engineers knowledgeable about building design and construction.

The task force evaluated conference findings relating to state policy. Senator Rogers incorporated the findings into Senate Bill 920, which was signed into law by the Governor in September, 1989, three weeks before the Bay Area earthquake on

October 17, 1989. The new law requires, among many things, the State of California to demonstrate earthquake hazard mitigating technology in three state structures -- two existing buildings and a new one. The existing and the new project have been selected. Senator Rogers has introduced two additional bills during the 1990 session. One bill modifies the law created by SB 920, and the other is a Constitutional amendment to provide incentives for businesses to retrofit earthquake hazard mitigating technology into existing buildings.

NEW POLICY DIRECTION NEEDED AT THE FEDERAL LEVEL

The federal government has yet to incorporate earthquake hazard mitigating technology, as defined in the new California law, into new building construction or in retrofitting existing buildings in seismically active areas. Additional studies of the 1989 Bay Area earthquake have been funded, but none are associated with design and construction of new buildings, or the retrofitting of unsafe, older buildings, to prevent damage to structures and contents. The federal government should assume a lead role in protecting federal buildings, contents, and function and encourage business leaders to take similar action with private buildings. The Japanese have have extensively reviewed California research and have over 60 projects underway using earthquake hazard mitigating technology, including base isolation. Meanwhile, the number of projects in the U.S. can be counted on one hand.

President Carter convened a task force after, Mount St. Helens erupted in May, 1980, to examine the seismic vulnerability of military and defense facilities. The task force completed its study and was disbanded by the subsequent administration with little action taken. Some of the nation's most critical military installations are located in earthquake prone areas and should be given immediate attention by the Department of Defense.

National defense strategy needs a complete reevaluation in light of the changes occurring in Eastern Europe. The likelihood of an intercontinental thermonuclear exchange, the justification for the defense policies of the past 40 years, has diminished. An article, scheduled to appear in the April, 1990, issue of the *Military Engineer,* the journal for the Society of Military Engineers, draws an analogy between an aggressor's first strike on the United States to an earthquake. The author, Dr. Alexander Tarics, states there are opportunities to negotiate solutions before a nuclear exchange, but negotiations with nature are impossible. (Mount St. Helens released the equivalent energy of a one megaton weapon).

A new concept of national defense should consider natural threats. Economic strength is as vital to national security as military strength. A major earthquake will have an immediate and long range effect on the nation's economy, since major destruction will occur to manufacturing centers -- targets -- and infrastructure with irreparable losses. The U.S. Geological Survey predicts a 50-60% probability of a major California earthquake in the next 30 years, and further postulates a $50 billion in property damage alone. No figures are available for long term losses. The Bay Area earthquake of October, 1989, was moderate by seismological standards. The 1906 San Francisco earthquake was over 40 times more powerful than the October 17 earthquake.

INDUSTRIAL AND DEFENSE IMPLICATIONS

Industrial firms have made themselves vulnerable with "just in time" manufacturing practices. The intent is to minimize inventory and establish a material flow system based on a continuous logistical flow. Single source suppliers are used for components and subsystems. A major earthquake in the California manufacturing centers will disrupt, and possibly destroy, the manufacturing flow. Any loss of production, even for a short period, could result in total loss of market share. The immediate damage may be slight, but the long range effects of the earthquake could be terminal. Manufacturing firms not directly effected by the earthquake are still at risk because of the vulnerability of their suppliers. One major computer company estimates that its in-house inventory represents a manufacturing capability of five days.

Defense installations, including research and development facilities, are equally vulnerable.

SUMMARY

The National Earthquake Hazard Reduction Program should be expanded to aggressively promote the use earthquake hazard mitigating technologies in existing and new buildings. By definition, earthquake hazard mitigating technologies are those which not only increase protection for life and safety but which also protect building structure, contents and functional capability. Funding the application the new technology into buildings, including defense facilities, should be of highest priority. Research and development should emphasize building design and modification to correct existing deficiencies.

The principal way to reduce the hazard of earthquakes is to design and construct buildings and structures to be less earthquake sensitive. However there is a tendency in the technical community to continue studying and gathering data indefinitely rather than commit drawings to manufacturing. An old mechanical engineering phrase is, "the time for study and design is over, and it is time to cut chips." Study and analysis of the earthquake hazard should continue, but with definite and timely goals in mind which emphasize implementation of findings into design and construction before the next major earthquake strikes.

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